Sky and TELESCOPE

Solar chromosphere photographs

★

Vol. XV, No. 4

FEBRUARY, 1956

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In This Issue:

Problems of the Solar Chromosphere

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Vol. XV, No. 4 FEBRUARY, 1956

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The principal articles are indexed in THE READERS' GUIDE TO PERIODICAL LITERATURE.

Astronavigation in the Air

NAVIGATION is a branch of applied science of increasing importance to travel by sea and air. One might think, however, that the tremendous speed of modern planes has long outdated the old-time use of celestial navigation.

This is not the case, but the methods of sea navigation have had to be shortened for use in the air, and today's jet aircraft are calling for seemingly impossible feats on the part of the navigator and his instruments. Insight into the nature of the problem can be gained from several articles in the September, 1955, issue of *Navigation*, the quarterly journal of the Institute of Navigation.

In a discussion of air power and aerial navigation, Major General Robert H. Terrill, deputy commander in the Strategic Air Command, points out that the skill of the navigating observer determines how well attacking planes can choose the time of day or night, the altitudes, and their approaches to the target. This is the concept of "qualitative mass" in modern warfare. He goes on to say:

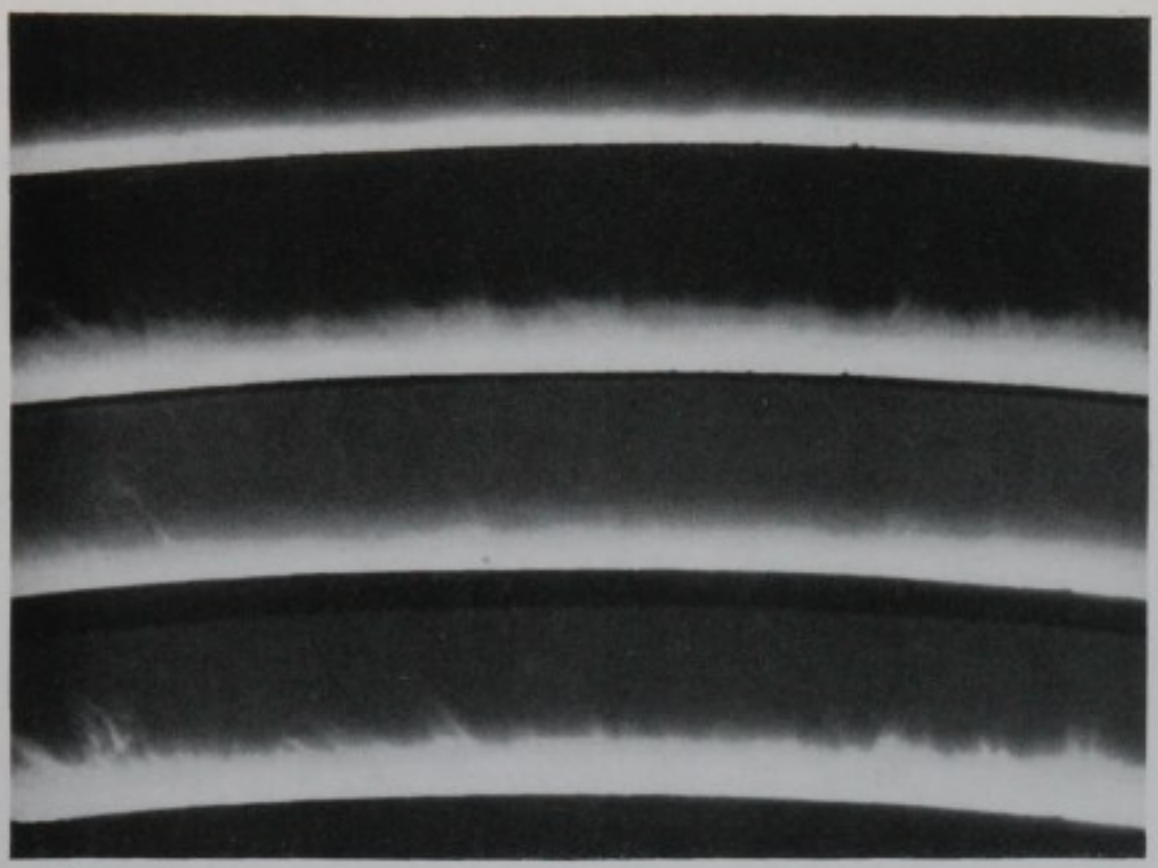
"And, ironically, in this time of electronic wizardry, the stars in their courses may well prove to be our best ally. Faced with the problem of electronic countermeasures, the Observer must still rely primarily on celestial navigation. And believe me, his problems have snow-balled as the speed and range of his aircraft have increased.

"It was a rather rude awakening, to say the least, for the navigator of a conventional type aircraft when he found himself in the dark nose of a jet for the first time. Formerly, he had a radar observer to augment his eyes. He had a bombardier to direct his weapons. Occasionally, he employed an assistant navigator to aid him and he was accustomed to traveling at a speed of approximately three miles per minute.

"Now he was alone and flying at eight miles per minute, using old techniques. Upon completion of his celestial observations and computations, he could figure on being about 128 miles from where his work showed him to be. If he found himself 'off course,' a series of ugly questions presented themselves. Had there been a wind shift? Was there compass error involved? Had it been a case of personal error? Meanwhile, his aircraft was still cruising along at eight miles per minute."

General Terrill outlined new instruments and other techniques to solve this problem that have been in use a short time with gratifying results. But supersonic flights again double the average

(Continued on page 158)



These simultaneous photographs of a 12-degree section of the sun's edge were secured with the Dunn camera, as described in the text. The numerous small bright spikes, particularly prominent in the lowest picture, are spicules. The scale is about one inch to 32,000 kilometers on the sun. Upper Air Research Observatory photographs.

Problems of the Solar Chromosphere

THE CHROMOSPHERE is the lower atmosphere of the sun, extending some 10,000 kilometers above the solar surface or photosphere. From the earliest observations of the chromosphere during total eclipses, its peculiar brushlike structure has fascinated astronomers, who have likened it to a burning prairie and described it as made up of luminous jets and spicules. For the last 15 years, astronomers have realized that sufficient nonthermal energy somehow passes outward through this zone to heat the overlying corona to a temperature of 1,000,000° centigrade or more.

Observational and theoretical problems of the chromosphere, that have long vexed solar experts, formed the subject of a symposium at the Troy meeting of the American Astronomical Society in November. The participants were John P. Hagen, Naval Research Laboratory; John W. Evans, Upper Air Research Observatory; Orren C. Mohler, McMath-Hulbert Observatory; and Richard N. Thomas, Harvard College Observatory. There was surprising agreement among these speakers in their general picture of the chromosphere.

The basic difficulty in observing the chromosphere is the overwhelming glare of scattered light from the main body of the sun. Much information has been obtained from the infrequent observations of total eclipses, when the moon cuts off the photosphere's light and permits us to see the bright-line spectrum of the chromosphere—this is called the flash spectrum because it appears only for a short time at the beginning and ending of totality. The chromosphere can also be observed with the spectroheliograph, which uses the light of a single element, such as hydrogen or calcium.

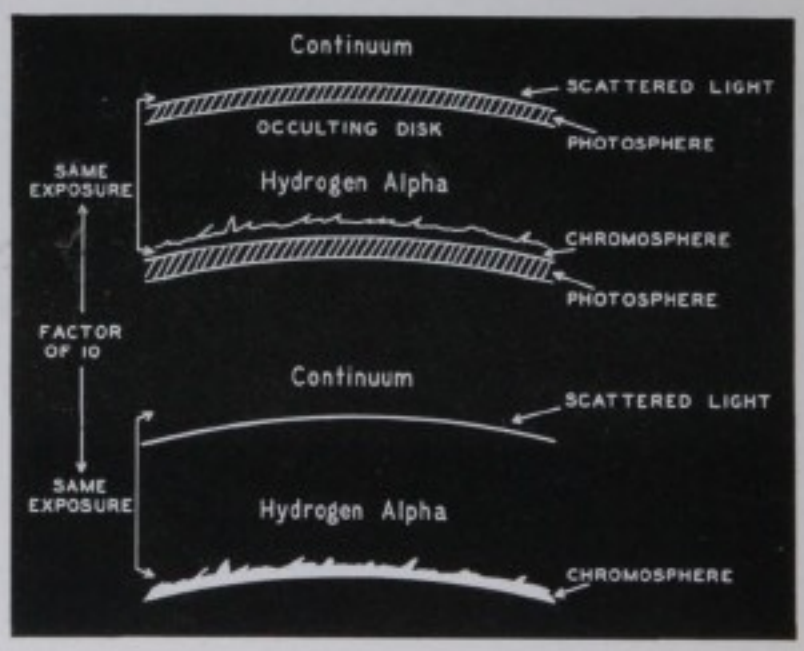
Dr. Evans pointed out that the difficulties and expense of eclipse observations are strong incentives to observe the chromosphere spectrum by other means, but that surprisingly little effort has been made in this direction. At Sacramento Peak, N. M., the Upper Air Research Observatory is "working the bugs out of a 16-inch coronagraph feeding a 13-meter spectrograph."

As for direct observation of the structure of the chromosphere, not much was done (except during eclipses) until the 1940's, apart from the visual work of Secchi around 1875. Our current concept of the visible chromosphere rests almost entirely on a few excellent eclipse plates and data obtained from three coronagraph-type telescopes with birefringent filters, located at the Pic du Midi in France, at Climax, Colo., and at Sacramento Peak.

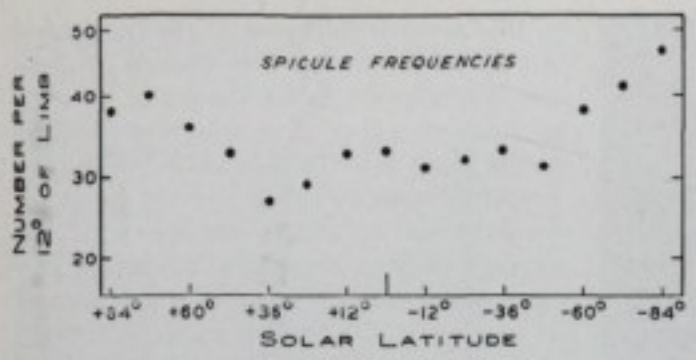
The Natural History of Spicules

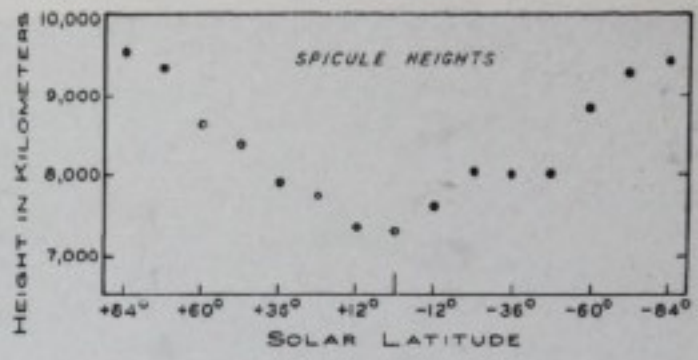
Dr. Evans' talk was largely based on remarkable motion pictures now being secured by Richard B. Dunn at the Upper Air Research Observatory. His multiple-image camera simultaneously photographs the sun's edge in light of the continuous spectrum and in the red light of hydrogen. Each picture shows the bright spikes or spicules that project above the 5,000-kilometer level of the unresolved chromosphere to heights ranging up to some 15,000 kilometers.

The Dunn camera utilizes a 15-inch singlet (nonachromatic) lens of 956 inches equivalent focal length and a hydrogen-alpha birefringent filter with a passband of 3.4 angstroms. A series of beam splitters in the optical system allows taking four simultaneous pictures of a region extending 12 degrees along the sun's edge. These pictures differ from each other in intensity, wave length, and in the occulting of the sun's limb, thus permitting evaluation of the scattered light and of seeing conditions. A complete absolute brightness standardization system is provided. Two types of 35-mm. pictures are taken, one a survey completely around the solar limb and the other a motion-picture film at the rate



This is a key provided by Richard B. Dunn to show the manner in which his photographs of the chromosphere are made. It may be compared with the picture above and with the front cover of this issue.





Averaging nine surveys of the edge of the sun on Dunn photographs, Miss Lippincott found the frequency distribution at the left. The variation of height with solar latitude, plotted at the right, is from six such surveys. Sproul Observatory diagrams.

of 16 frames per minute; the latter becomes accelerated 60 times if projected at a rate of 16 frames per second.

In the illustration opposite and on the front cover, the topmost portion shows the edge of the sun in the light of a continuous part of the spectrum close to the wave length of the hydrogen-alpha line in the red. The picture below it is the same, but the passband has been shifted a few angstroms to admit only hydrogen-alpha light. In the lower two parts, the occulting disk has been moved upward to cover the sun's edge completely, but the effective exposure is 10 times as great as in the upper two pictures. Thus, the top and third strips are the same except for occulting and intensity; similarly, for the second and fourth. The spicules are best seen in the fourth section, but some of them are visible in the third one, where the Doppler shift caused by their motions in the line of sight has altered their apparent wave lengths into that of the continuum adjacent to the hydrogen-alpha line.

Previously seen in polar regions of the sun during total eclipses, the solar spicules were first observed with a coronagraph by Walter O. Roberts at Climax, in the early 1940's. Mr. Dunn's camera now makes it possible to carry on a detailed study of their rapid changes to a degree of resolution unknown before. His films have been partially analyzed by Sarah Lee Lippincott, of Sproul Observatory, and her results were presented at the meeting, based on Dunn pictures for a period of six weeks during the summer of 1955.

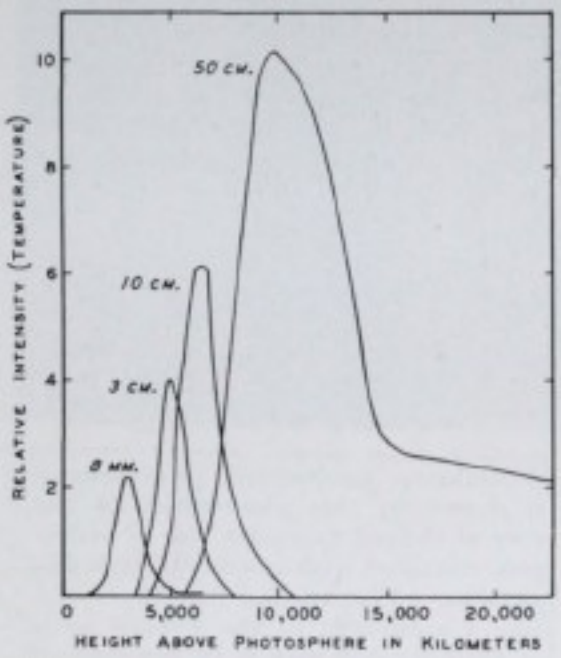
Spicules can be found at all solar latitudes, but they are most common near the poles and less numerous in the zones where sunspots and prominences are frequent. For 77 spicules, a minimum average lifetime of five minutes was determined by Miss Lippincott. As observed in red light, spicules grow in height at an average rate of 19 kilometers per second; nearly half of them fade out at maximum height, but the rest are observed to shrink again. It is conceivable that these changes do not mean actual transport of matter, but result instead from varying conditions of excitation of the chromospheric atoms.

Dr. Evans pointed out that there are about 1,000 spicules visible on the solar limb at any time. They are observed with heights ranging from 20,000 down to 9,000 kilometers in rapidly increasing numbers. At still lower heights the numbers decrease, but most observers state that this is due to observational selection; for instance, Dr. Evans believes that the pictures Miss Lippincott used would not permit a complete count below 9,000 kilometers. If the frequency curve from higher levels is extrapolated downward, he expects to find about 2.4 spicules per 1,000 kilometers of the sun's limb at a height in the chromosphere of 5,000 kilometers. The unresolved lower chromosphere may be entirely composed of spicules, and the latter may be as numerous as the photospheric granules that give the rice-grain appearance to the sun's surface when it is observed in white light. This supports earlier suggestions that the spicules are formed from the granules, carrying material and kinetic energy to the interspicule chromosphere and the corona, most of the matter falling back into the sun.

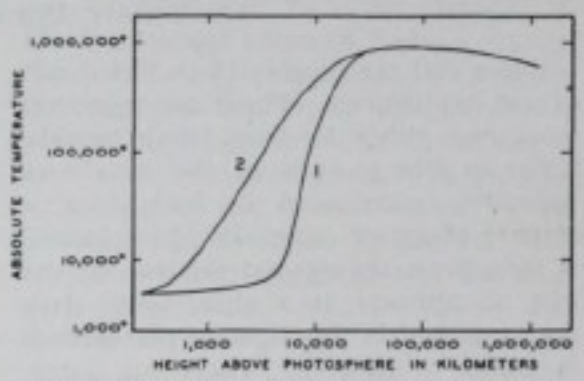
How Radio Studies Fit In

A closely related concept of the chromosphere comes from radio observations of the sun, discussed by Dr. Hagen. It has been known for some time that solar radio emission at wave lengths of a meter or so originates in the corona, while radiation at centimeter wave lengths comes from the chromosphere. In confirmation of this, and in accordance with theory, it was found as early as 1947 that the sun was brightest at its edge in centimeter radiation.

But more recent observations with the 50-foot radio telescope at the Naval Research Laboratory showed a new effect that could not be explained by a sun assumed to be made up of smooth layers with radial symmetry. In 8-mm. radiation, which originates deep in the chromosphere, there was not only the familiar limb brightening but also a pronounced brightening toward the center of the sun's visible disk.



These curves by Dr. Hagen indicate, for four wave lengths, the contribution of each level in the solar atmosphere to the observed microwave radiation from the sun. The shorter wave lengths originate deeper in the chromosphere.



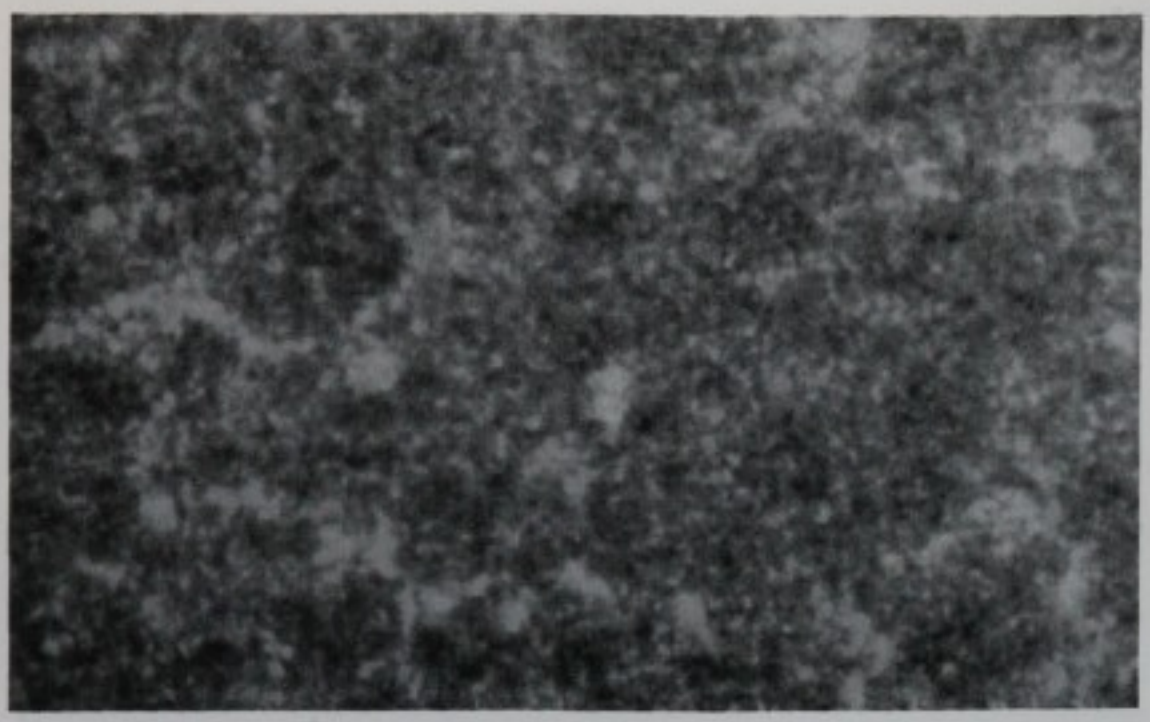
Dr. Hagen's model calls for a much earlier increase of temperature with height in the interspicule material (curve 2) than in the spicules themselves (curve 1). Naval Research Laboratory diagram.

Dr. Hagen has been able to account for this new effect in terms of a spicule model of the chromosphere. Cool, dense spicules are pictured as embedded in the hotter, more tenuous interspicule material, and the latter might be regarded as an extension of coronal gas toward the photosphere. The model would require spicules with average heights of 10,000 kilometers and with bases about three or four seconds of arc wide.

In his calculations, Dr. Hagen assumed that the spicules are pyramidal or conical in shape, and sufficiently numerous for their bases to cover the photosphere completely. "This two-fluid model," he said, "makes it possible to reconcile with radio observations those optical data that require matter at temperatures of 15,000° low in the chromosphere."

Looking Down into the Chromosphere

The third symposium speaker, Dr. Mohler, described the major features of chromospheric structure revealed by routine spectroheliograms made, for instance, with a passband of half an angstrom at the center of the K line of calcium. The background is made up of mottled gray



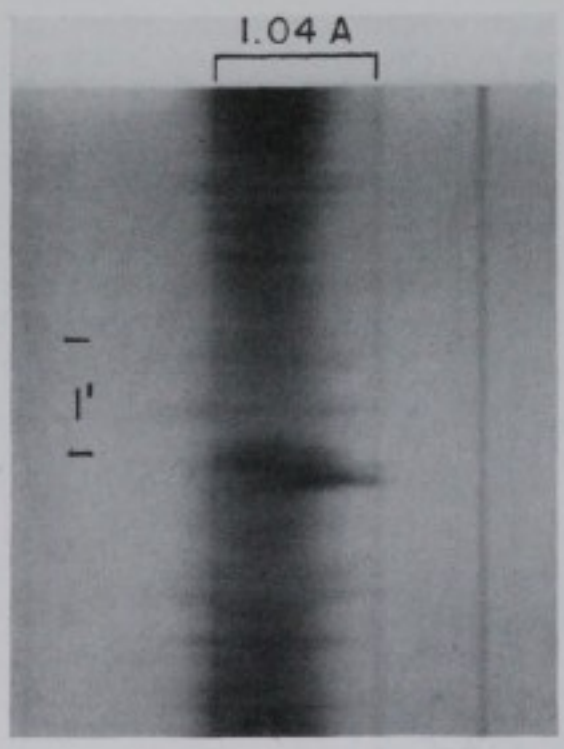
The fine structure of the chromosphere, photographed in calcium light at Yerkes Observatory. This spectroheliogram, of excellent quality, was taken on September 22, 1903, when the seeing was exceptionally good. This reproduction has a scale of 2.4 seconds of arc per millimeter. From the "Publications" of the Yerkes Observatory, University of Chicago.

features that are roughly 10 to 30 seconds of arc in diameter. These are separated from each other by long, bright streaks three to five seconds of arc wide and sometimes continuous in length for a minute of arc or more. If a prominence is seen projected against the disk of the sun, it appears as a thin, long, dark marking, and in this aspect a prominence is called a filament. There are large, bright areas called plages, and only within them can sunspots be found—sometimes the spots are covered by the plages.

Spectroheliograms of good quality record fine details of the same size as the granules on ordinary pictures of the photosphere. In a calcium spectroheliogram, objects larger than two seconds of arc seem to be most numerous in two groups, one averaging five seconds in size, the other 15 seconds. The latter give ordinary calcium spectroheliograms an orange-peel appearance and seem to be dark clumps of smaller details.

Dr. Mohler showed lapse-time motion pictures of the continual movement of chromospheric filaments; he pointed out that the moving dark clumps in the pictures were the tops of small prominences that wave back and forth over the sun's surface. These clumps appear to have a minimum average lifetime of about 90 minutes and a maximum of several days. He believes the filaments disappear and re-form in the same positions for fairly long periods; large prominence filaments also often have a similar behavior.

A spectroheliogram is made by scanning the sun's disk in the light of a single strong spectral line such as hydrogen alpha or calcium K. Now the new vacuum spectrograph of the McMath-Hulbert Observatory (*Sky and Telescope*, September, 1954, page 372, and July, 1955, page 372) has enabled Dr. Mohler to make detailed studies of the structure of the lines themselves. The instrument has a spectroscopic resolving power of more than 500,000 and the dispersion can be as large as 25 millimeters per angstrom. The illustration shows the appearance of the central core of the hydrogen-alpha line, which is formed in the highest layers of the chromosphere.



A hitherto unobserved phenomenon is shown by this photograph of the core of the red spectrum line of hydrogen, obtained with unusually high dispersion. The vertical length of the line corresponds to the narrow strip of the solar disk viewed by the spectrograph slit. Line-of-sight motions of hydrogen gas, varying along this strip, cause small changes in wave length of corresponding parts of the spectral line, giving rise to its conspicuous streakiness. McMath-Hulbert Observatory photograph.

The average thickness of the horizontal streaks in the line is five seconds of arc—the line appears to be composed entirely of small elements. The width of the line varies from $\frac{3}{4}$ to $1\frac{1}{4}$ angstroms; its center is shifted toward either the red or violet by as much as 0.2 angstrom, with the average shift of about 0.01 angstrom corresponding to 0.5 kilometer per second as motion in the line of sight. Although ordinary prominences on the sun have velocities in the range of 10 to 20 kilometers per second, 0.5 is close to the average of some of the clumps of filaments shown in spectroheliogram motion pictures.

The streaked structure of the hydrogen line continues to within five seconds of the sun's edge. Similarly, chromospheric structure on good spectroheliograms is visible very close to the limb. These facts indicate that details on the sun causing the streaks in the line centers must be at a rather high level in the solar atmosphere.

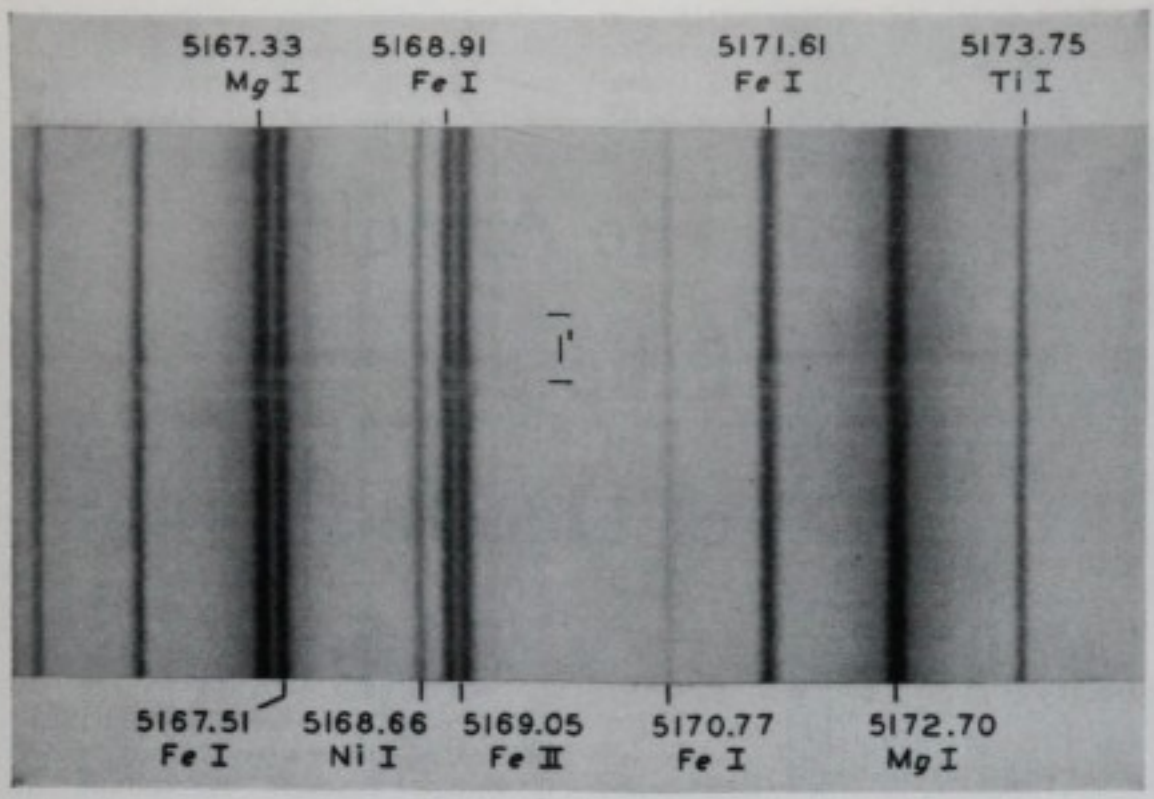
Many lines, in addition to hydrogen alpha and calcium K, the favorites with users of the spectroheliograph, show similar spectroscopic structure. The streaks in the sodium D lines have the same three- to five-second width as hydrogen and calcium, and their velocity variations are nearly all less than one kilometer per second. Pictured opposite is the similar behavior of lines of neutral and ionized iron, nickel, and magnesium, in a region near the center of the disk of the sun.

Dr. Mohler pictured the chromosphere, on the basis of spectroscopic and spectroheliographic observations, as a layer based on the photosphere, in which are rooted minute filaments that, except for size, are very much like the large prominence filaments. The most common motions resemble those in prominences—arched motions—generally less than one kilometer per second. Like the filaments, the observable small-scale structure of the chromosphere seems to have considerable permanence, with lifetimes of the order of hours perhaps not uncommon. The intensity variations are about two per cent, on the average, of the intensity of the continuous background at the wave length of observation.

The Chromospheric Problem

The viewpoint of the theoretical astrophysicist was expressed at the symposium by Dr. Thomas. It is not yet possible, he said, for the theoretician to present a first detailed model of the chromosphere, nor to identify with certainty the phenomena giving rise to it. The observational basis for an empirical model of the chromosphere is still incomplete, particularly for those features that appear variable.

The over-all "chromospheric problem" has taken quite different forms at different times, Dr. Thomas said. Twenty years ago, astrophysicists sought to interpret



Another observation of small-scale motions in the solar chromosphere, as revealed by the streaky character of spectrum lines of neutral magnesium, iron, and nickel, and ionized iron, here crossing a bright plage near the middle of the sun's disk. McMath-Hulbert Observatory photograph.

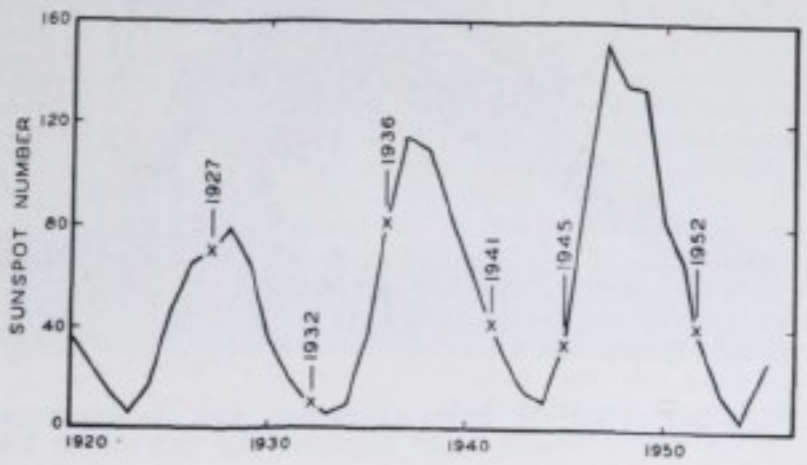
the anomalously great extent of the chromosphere as the existence of a system of gas motions. Some astronomers thought this gas motion supported the chromosphere in a ballistic fashion, others that the chromosphere was simply a composite of gas streams. At that time, it was generally assumed that radiation was the only source of energy for the chromosphere. By eight years ago, however, this assumption was rapidly being dropped, and the system of gas motions was looked upon as a nonradiative energy source.

Today, we are essentially trying to decide how much energy the gas streams supply to the chromosphere and how much of its mass they contain. It is believed that the temperature rise is already well under way in the low levels of the chromosphere.

The greatest difficulty arises in departures from thermodynamic equilibrium of atoms in the various energy states. For knowledge of "a" temperature and "a" density no longer gives directly the relative number of atoms producing the various spectral lines, and we have essentially a different temperature for each atomic energy level. So it is not a simple matter to work backward from intensities of various spectral lines to get temperature and density distributions.

The best current opinion seems to be that we cannot satisfy all the observations with a simple model of the chromosphere possessing spherical symmetry, but we require one containing hot and cold regions at the same height. Thus, the optical results agree with the general model presented by Dr. Hagen from the radio data. The probable sizes of the regions suggest identifying the cold component with the spicules and the hot with the interspicule medium.

To aid studies of the chromospheric problem, the Harvard astronomer asked for spectroscopic measurements of the spicules, and for detailed observations of the chromosphere both inside and outside of eclipse. We now realize that the structure of the chromosphere varies significantly over the cycle of solar activity; hence data gathered from different stages of the cycle cannot safely be combined. Flash spectra at the 1958 and 1959 total eclipses would be particularly valuable, for then we will have the first chances for modern eclipse observations during sunspot maximum since 1936, when only limited data were obtained.



The course of the sunspot cycle in recent years, as indicated by relative numbers of spots. Crosses show the dates of observed total eclipses of the sun; the last three all fall near minima of solar activity. Modern eclipse observations of the chromosphere at maximum of the cycle are therefore relatively scanty.

MODEL OF AN ARTIFICIAL SATELLITE DISPLAYED

Visitors to New York's Hayden Planetarium can see a full-scale model representing one of the man-made moons that the Department of Defense is to launch during the International Geophysical Year, in 1957-58. The model is a transparent plastic globe, 18 inches in diameter weighing 25 pounds. It rests on a pedestal that simulates the nosepiece of the third stage of the rocket which is to carry the artificial satellite aloft.

Inside the transparent shell can be seen a mock-up of the complex electronic equipment that is to record conditions some 200 miles above the earth's surface and transmit its findings to ground stations by radio. The intensity of cosmic rays, the sun's ultraviolet light, atmospheric electricity, and the earth's magnetic field will all be subjects for research from satellites.

The model on display in New York was designed and built by Herbert R. Pfister, associate editor of *Popular Science Monthly*, after consultation with scientists engaged in Project Vanguard. He pointed out, however, that his model is merely an "educated guess." A preliminary contract has been awarded to the Glenn L. Martin Co., Baltimore, Md., makers of the Viking rocket, for construction of the actual satellites to be sent aloft in 1957-58.

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The new rates will be $5.00 per year in the United States and possessions; $9.00 for two years; and $13.00 for three years. Add $1.00 per year for Canada, Mexico, and all countries of the Pan-American Postal Union, making the total subscription $6.00 for one year; $11.00 for two years; and $16.00 for three years. Add $2.00 per year for all other foreign countries, making the total subscription $7.00 for one year; $13.00 for two years; and $19.00 for three years. Canadian and foreign remittances should be made in United States currency.

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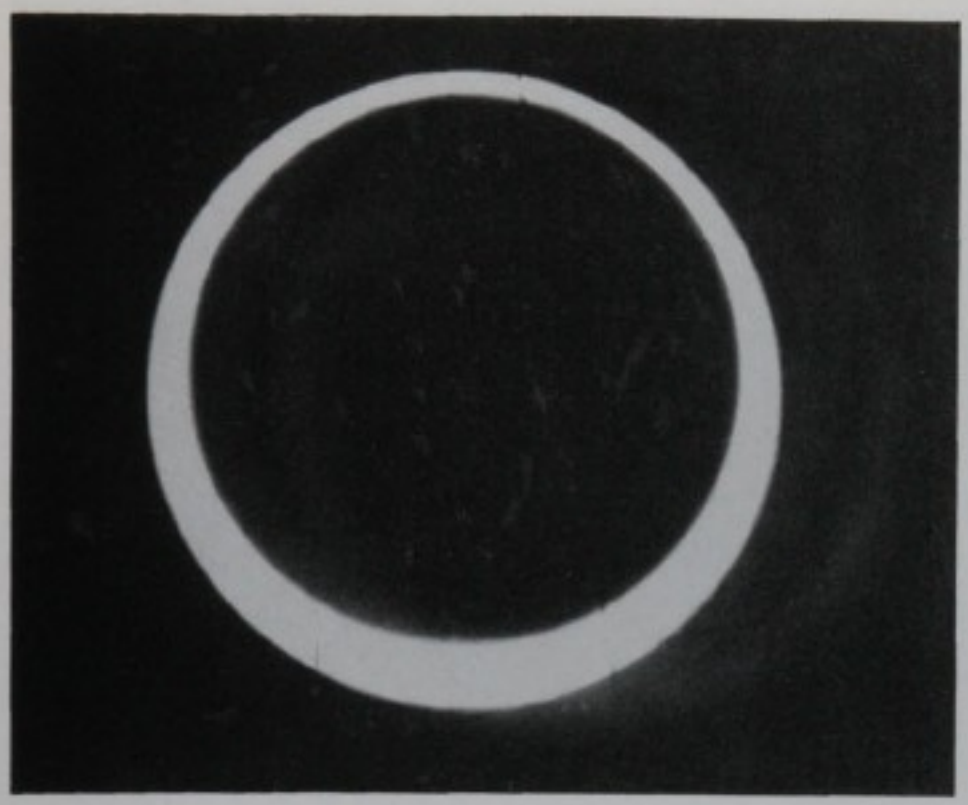


The Annular Eclipse of December 14th

Near the middle of the annular eclipse of December 14, 1955, two minutes after second contact, this picture was taken at Khartoum, on the central line. Photographic effects in the enlargement cause the ring to appear larger than its actual 1/20 of the sun's diameter. All photographs with this article are courtesy U. S. Air Force.

ONE of the finest celestial sights of 1955 was visible to Eastern Hemisphere watchers December 14, 1955, when all but a thin ring of the sun was obscured in an annular eclipse, along a narrow zone stretching from the Sudan and Ethiopia across the Indian Ocean, just south of Ceylon, through Burma and Thailand to Formosa.

It was a noteworthy event in several ways. It featured one of the largest eclipse efforts on record, as 11 American expeditions under sponsorship of the Air Research and Development Command occupied stations along the path of annularity. There was especially close cooperation between amateur and professional astronomers, some of the sites being manned entirely by amateurs. The path of this eclipse intersected the paths of the total solar eclipses of February 25, 1952, and June 20, 1955.

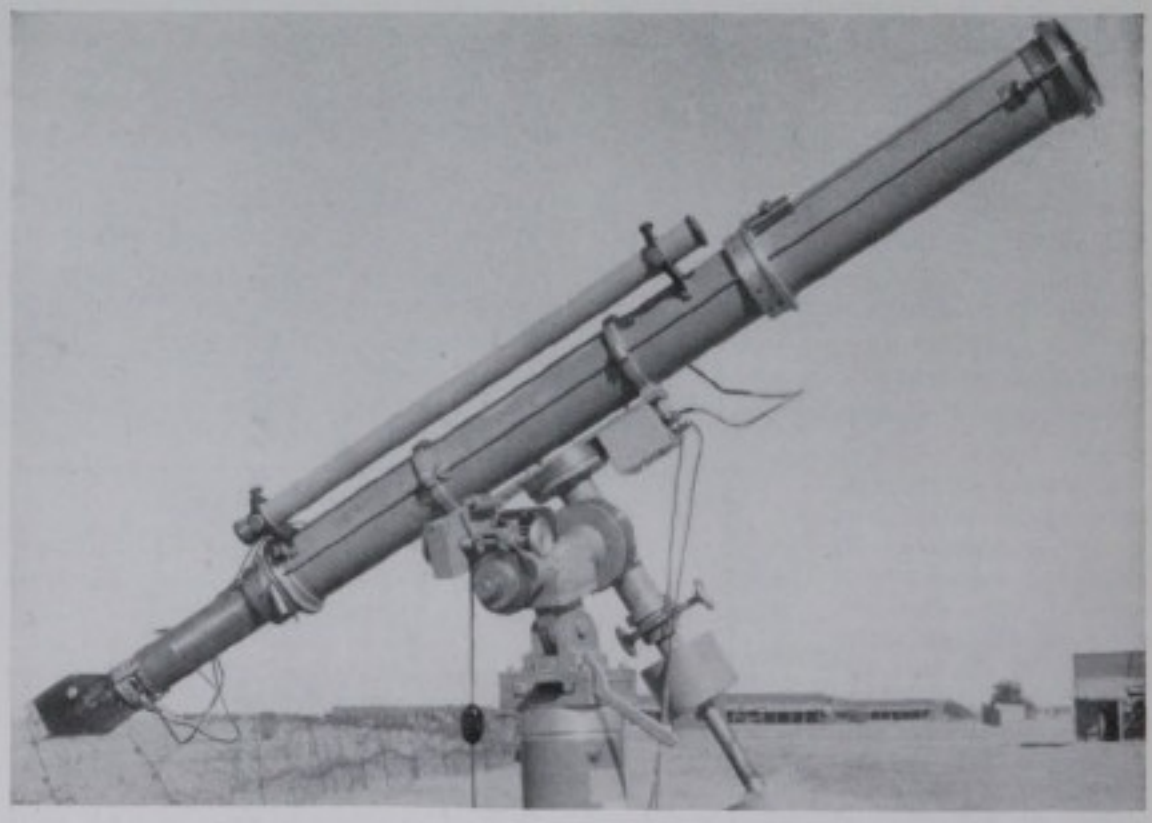
At eclipse time on December 14th, the moon was only one day before apogee—the farthest point in its orbit from the earth—and its disk was therefore too small to cover the sun completely. The longest duration of the ring phase was 12 minutes 9 seconds, at a point in the Indian Ocean southwest of Ceylon. If you had been on the central line of the eclipse track, at mid-eclipse you would have seen the black silhouette of the moon surrounded by a narrow ring of light 1½ minutes of arc wide, 1/20 the apparent diameter of the sun.

With only 82 per cent of its area obscured, the sun was still very bright during the annular phase, and this eclipse afforded no opportunity to observe the faint solar corona that becomes visible during total eclipses. The purpose of astronomers who traveled halfway around the world to observe the event was geodetic, to obtain data for a more precise determination of the size and shape of the earth. In principle, if some specific phase of a solar eclipse is accurately timed at two widely spaced geographical points, then the distance between these two places can be inferred from the known speed at which the moon's shadow sweeps across the earth's surface.

To exploit this opportunity, a comprehensive campaign was planned by the Geophysics Research Directorate, Air Force Cambridge Research Center, with Robert Fitzpatrick, Terrestrial Sciences Laboratory, acting as project scientist. All the expedition sites were visited beforehand by parties from the American Geographical Society, of New York City, who selected appropriate observation points and made advance arrangements with local authorities.

Under a contract with the Air Force, the over-all responsibility for planning the observations, selecting the observers, and reducing the data was placed in the hands of Rev. Francis J. Heyden, S.J., director of the Georgetown University Observatory. He employed two methods of determining the exact times of various phases of the eclipse, one photographic, the other photoelectric.

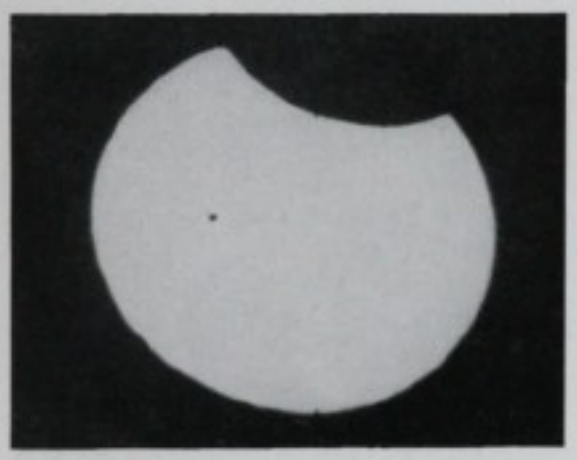
The picture below shows one of the five-inch refractors used to photograph



At five of the Air Force expedition sites, the photographic method was used with 5-inch refractors like this one at Khartoum.

the moon's position against the sun. The magazine at the eyepiece end was loaded with 118 2¼-by-3¼-inch plates, one of these being exposed every two minutes during the partial phases and every 30 seconds during the annular phase. The sun's image is about the size of a one-cent piece. The shutter over the objective is controlled by a rod that runs alongside the tube. From measurements on the photographs of the changing dimensions of the solar crescent and annulus, the relative positions of the sun and moon can be determined for each site.

In the second method, the light curve of the eclipse is recorded by a simple apparatus, pictured at the right. It contains a photomultiplier for measuring the changing brightness of the unobscured part of the sun. With certain corrections, the time of minimum light corresponds to the instant when the axis of the moon's shadow passes the observer. The aperture



This is the way the sun looked at Khartoum as it rose during the early moments of the eclipse. The moon has already taken a "bite" out of the top of the sun's disk, which is deformed by atmospheric refraction.

of the tube is half an inch, and it is kept pointed to the sun by manual control. The voltage for the photomultiplier tube is supplied by two mercury cells and a Victoreen unit.

The map below shows the locations of the 11 sites: 1. Khartoum; 2. Gedaref; 3. Aiscia; 4. Hargeisa; 5. Colombo; 6. Mergui; 7. Koko Katheim; 8. Bangkok; 9. Siem Reap; 10. Hue; 11. Kang shan.

The westernmost of these eclipse parties was stationed near Khartoum, in the Sudan, where the sun rose already in partial eclipse, as shown by the photograph. Here Father Heyden himself was in charge of a seven-man group of scientists from the Washington, D. C., area. Their instrument shelter was an empty mud building only 50 feet from the spot where Father Heyden had observed the total eclipse of 1952!

At Khartoum both photographic and photoelectric observations were carried out successfully, with a sky as clear as could be wished for. Although he has been on many eclipse expeditions, this was the first one since 1947 at which Father Heyden could look skyward from his duties and catch a glimpse of the eclipse itself. He noted an interesting phenomenon:

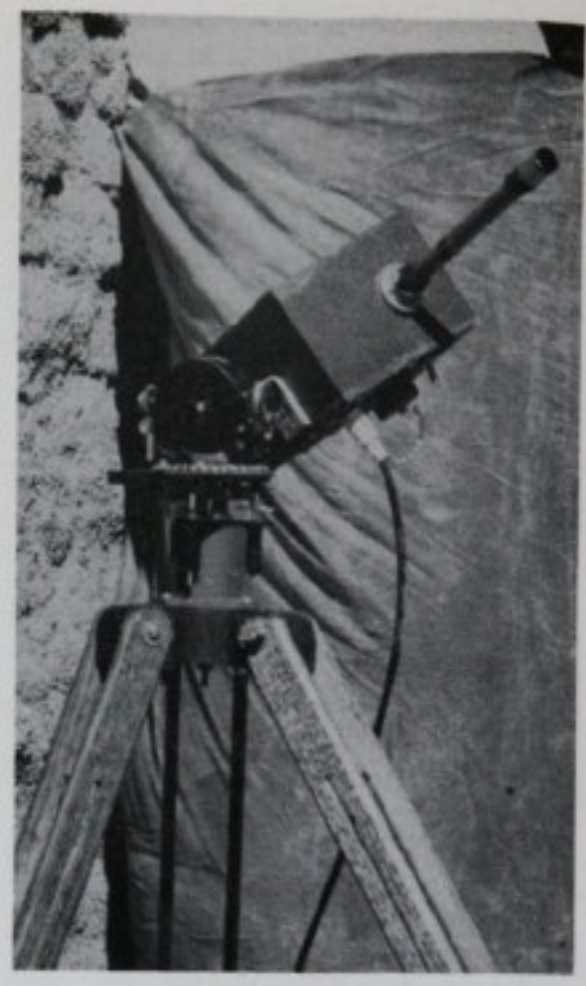
"It was a beautiful sight and an amazing one. While taking a quick look at it without a filter, I noticed that the annulus appeared surrounded by concentric diffraction rings, very much like the 'pilot's halo' that one sees on the clouds underneath a plane while the sun is almost overhead. This could have been purely subjective."

Some 200 miles to the east, at Gedaref, in the Sudan, the second American team completed its photoelectric observations under perfect weather conditions. This group, led by Jay F. Kunze, Allegheny Observatory, included A. L. Ott, R. L. Scherer, D. J. Peart, and W. A. Love, some of them members of the Amateur Astronomers Association of Pittsburgh.

Station 3, at Aiscia, Ethiopia, was manned by professional astronomers from the Goethe Link Observatory, Indiana University, headed by Dr. James Cuffey. Here again excellent weather favored photoelectric observations.

At the next eclipse site to the east, Hargeisa, British Somaliland, members of the Milwaukee Astronomical Society waited for the eclipse, but overcast skies permitted only glimpses between clouds. Here E. A. Halbach, a former president of the Astronomical League, had prepared for both photoelectric and photographic observations, with the assistance of W. B. Albrecht, R. R. Fink, W. J. Konig, J. H. Uporsky, K. E. Kissell, and R. R. Lee.

In Ceylon, where mid-eclipse occurred shortly after local noon, only the photographic program was planned, as this island lay just outside the zone of annular eclipse. Site 5 was about seven miles south of Colombo, at the Ratmalana international airport. But passing clouds unfortunately interfered with the work

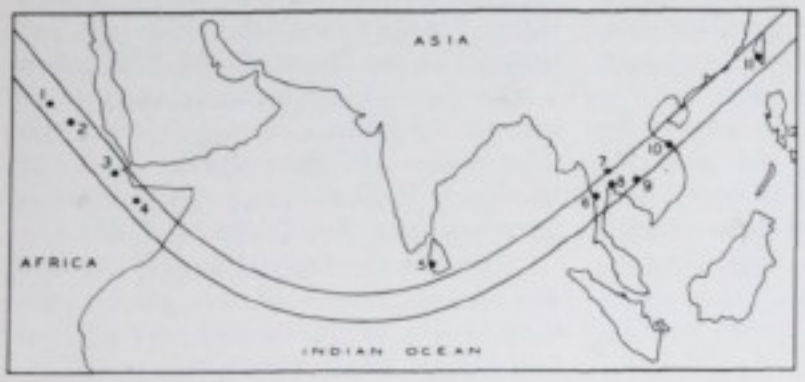


The photoelectric light-measuring apparatus as set up at Khartoum.

of the Johns Hopkins team headed by Dr. I. H. Shroader.

As we continue eastward in the direction of the motion of the moon's shadow, we find the next party at Mergui airport, in Burma, prepared for both photographic and photoelectric timing of the eclipse. Located just north of the central line, this station was less than five miles from a first-order geodetic control point at Bodaung. The Burmese army assisted in determining by survey the precise location of the observation point with respect to this bench mark. At Mergui, D. C. Whitmarsh was leader of a group of observers from Pennsylvania State University.

Two expeditions were flown into Thailand. Dr. Morris Davis, astronomer at the University of North Carolina, was in charge of the party at Koke Katheim. Their observing place was a hilltop close to the artillery training center of the



Left: A sketch map to show the location of the Air Force expeditions.

Right: The central cross in this plaque at Khartoum marks the exact position to which a geodetic survey must be tied, for the final reduction of the eclipse observations.

Royal Thai Army. Not only was a road to the top of the hill cleared by army personnel, but the summit was leveled off in preparation for the eclipse. When the crucial moments came, however, the sun was veiled by stratus clouds, and while the scheduled photometric observations were carried out, their value appeared questionable.

The other site occupied in Thailand was about eight miles northeast of Bangkok, the capital. Here the Swarthmore College party headed by L. Frederick saw the sun covered by cirrus clouds throughout the eclipse. Nevertheless, the photoelectric records secured are expected to be of fairly good quality, but the photographic observations of the positions of the moon against the sun were more seriously affected.

Two further parties were located on the southeast Asian mainland. Rev. Edward Hauber, S.J., and his team from Loyola College, Baltimore, Md., went to Siem Reap, Cambodia, close to the southern limit of the annular zone. Their program consisted of photoelectric observations only. At Hue, in South Viet Nam, F. J. Doyle's Ohio State party managed to complete their observations through heavy overcast.

Conditions were better for the easternmost expedition, near the airport at Kang shan, in Formosa, where the eclipse took place in the late afternoon. Here the Yale University Observatory party, under Donald S. Kimball, set up instruments on the flat cement roof of a small house atop a low hill. About an hour before the eclipse, some dismay was caused by failure of the time-signal recorder, but this was traced to a burnt-out vacuum tube, and the photoelectric observations were carried out successfully.

It will be some time before the final results of this extensive campaign can be assessed. Under the astronomical guidance of Father Heyden, thousands of photographs must be measured and reduced and the photoelectric tracings must be analyzed. Extensive geodetic operations will be needed to establish definitive longitudes and latitudes of the expedition sites. The encouraging reports of the observers offer promise that this great scientific effort, when combined with the results of similar Air Force programs at several other recent eclipses, will eventually give us a better knowledge of the size and shape of our planet.

ASTRONAVIGATION IN THE AIR

(Continued from page 151)

speed and introduce further problems.

It is evident that the navigator must have very rapid means of reducing his sights on the stars, planets, sun, and moon. Perhaps the high-precision computer for automatic solution of the celestial triangle developed by Gene R. Marner, Collins Radio Company, will make possible an automatic celestial navigation system. In this same issue of *Navigation*, Mr. Marner writes:

"The fundamental computation burden of the navigator is to find the altitude which corresponds to given values of declination, local hour angle and latitude. In recent years a need has risen for a computer which furnishes both altitude and azimuth for the purpose of directing an altitude-azimuth mounted radio telescope so it will follow a point on the celestial sphere."

The basic elements of the computer are electromechanical resolvers with compensating windings and buffer amplifiers. These are commercially available with functional errors less than one part in 2,000, and Mr. Marner has used them to build an experimental bench-model computer that has given satisfactory results.

In a series of 351 trials, the probable error of altitude determinations was only 0.9 minute of arc, with the maximum error 3.5 minutes. Except for celestial objects within 10 degrees of the zenith, the azimuth error was similar, and for 299 cases of altitude less than 70°, the probable error was 0.8 minute, the maximum error again 3.5 minutes.

Such a computer can be designed for portable or even airborne use, and when combined with a radio sextant (*Sky and Telescope*, October, 1954, page 427) may provide an automatic celestial navigation system that would observe the sun by day and the moon by night, usually without interference by the weather. The radio sextant was developed by the Collins Radio Company for the Navy's Bureau of Ships.

In the third article, "Polar Airline Navigation," Swedish navigator E. S. Pedersen lists the various types of polar navigation equipment in use or to be installed in planes making regular commercial flights across the north polar regions between the Eastern and Western Hemispheres. Since the first flights from Scandinavia to Los Angeles in November, 1954, several hundred trips have been carried out with no unexpected difficulties. In the fall of 1956, flights will probably begin with DC-7C's from Scandinavia to Anchorage, Alaska, thence to Tokyo.

The Scandinavian Airlines System has found that, even in arctic areas where the magnetic compass is fully reliable, an aircraft is kept much better on its heading by a Polarpath gyro, either with latitude integration or compensated for zero-degree drift for the mid-latitude of the flight. But the stars play their very important part:

"As soon as the aircraft has reached cruising altitude the Polarpath gyro is checked by astro for correct synchronization. If there should be any difference between the grid heading found by astro and the gyro heading, the Polarpath gyro is reset to indicate correct grid heading. From this point on the gyrograph is started and the Polarpath gyro as well as the Gyrosyn gyro are checked every half hour by astro throughout the rest of the flight."

Mr. Pedersen points out that radio facilities in the Arctic are available, but that too much reliance on them may easily lead to disaster. He says,

"Astro navigation is of course the primary means of fixing the aircraft's position on the trans-arctic routes. Three star fixes are taken every hour during flight in wintertime, and during summertime sun position lines are taken every half hour in connection with the heading checks."

ZEISS PLANETARIUMS TODAY

In a letter to Joseph M. Chamberlain, general manager of the American Museum-Hayden Planetarium, K. A. Bauer, of Carl Zeiss, Inc., New York City, has given the present status of Zeiss planetarium installations in all parts of the world. It is now 30 years since the first Zeiss instrument was put into operation in Germany.

At Munich and the Hague, smaller Zeiss instruments are in operation. Full-sized projectors are in use at six places in the United States (Chapel Hill, Chicago, Los Angeles, New York, Philadelphia, and Pittsburgh), and at Brussels, Hamburg, Jena, Milan, Moscow, Osaka, Paris, and Rome. Four of these, Brussels, Chapel Hill, Osaka, and Paris, were newly opened or reopened after World War II. The Chapel Hill instrument was formerly in operation in Stockholm.

Fully destroyed and no longer in operation are the planetariums of Berlin, Bremen, Düsseldorf, Dresden, Hannover, Leipzig, Mannheim, Nuremberg, Stuttgart, Tokyo, and Vienna.

Zeiss planetariums are under consideration for Sao Paulo, Brazil; Caracas, Venezuela; and London, England (at Madame Tussaud's), and will probably be opened within a year or so.

OPTICAL MEETINGS

The spring meeting of the Optical Society of America will be held in Philadelphia at the Bellevue-Stratford Hotel on April 5-7. The year 1956 marks the 250th anniversary of the birth of Benjamin Franklin, and the OSA will participate in the international celebration.

The meeting, as usual, is open to all interested persons. Nonmembers may obtain copies of the program from Dr. Stanley S. Ballard, Scripps Institution of Oceanography, San Diego 52, Calif.

Preceding the Optical Society meeting, the fourth congress of the International Commission of Optics will take place in Cambridge, Mass., March 28-April 3.

NEWS NOTES

By Dorrit Hoffleit

MORE SATELLITES?

For three planets, Mercury, Venus, and Pluto, no satellites have been discovered. Robert S. Richardson, Mount Wilson and Palomar Observatories, has considered the likelihood that moons of these planets may eventually be found. In *Leaflet* No. 316 of the Astronomical Society of the Pacific, he concludes that the chances, though not good, are "not quite as dim as might appear at first glance."

On the basis of the three-body problem, Dr. Richardson tabulates the limiting distances, for all the planets, at which a small moon could survive without escape from the parent planet, and the corresponding periods of revolution. In the case of Mercury, the maximum angular separation from the planet would be only 10 minutes of arc, period 63 days, at a distance of 138,000 miles. Observational difficulties, because of Mercury's proximity to the sun, practically rule out the feasibility of a search.

For Pluto, it is unlikely that a moon could be picked up unless it were brighter than the 20th magnitude; it would have to be at least 200 miles in diameter and 100,000 miles from Pluto for discovery.

Venus is the most promising case. A satellite 50 miles or more in diameter should already have been discovered. Search for smaller bodies could best be made at the time of Venus' greatest brilliance, about 36 days before and after inferior conjunction. A satellite 44 miles across might then appear of the 10th magnitude, while one three miles in diameter would be about 16th magnitude. But again Venus' proximity to the sun in the sky would hinder observations; visual observations in the twilight sky might prove more rewarding than photographic work. Dr. Richardson points out that three of the most elusive satellites in the solar system, Deimos and Phobos around Mars, and Jupiter V, were discovered visually.

DIAMETER OF PLUTO

The planet Pluto, it is pointed out by J. Kordylewski, of Krakow Observatory, occults one star of magnitude 15 or brighter per year, on the average. At present such occultations are rarer, because the planet is moving through a star-poor region.

However, on February 25, 1956, Pluto will pass in front of the spiral galaxy NGC 3162, and Dr. Kordylewski suggests that observations of the phenomenon with very large telescopes may clarify the vexing problem of Pluto's diameter. The currently accepted value of 0.5 second for the diameter implies an improbably high density; but if Pluto reflected sunlight like a convex mirror only the central part of its disk would be visible, and its diameter could be larger. These two possibilities might be distinguished when Pluto is seen silhouetted against a luminous nebular background.

The 12.3-magnitude galaxy is 1.4 by 1.1 minutes of arc in size, and is situated at $10^h\ 10^m\ 45^s$, $+22°\ 59'.1$ (1950), near Zeta Leonis. Pluto will be 0.4 minute of arc south of the center of NGC 3162 at 7^h UT on February 25th; its passage across the spiral will take about 24 hours, according to Dr. Kordylewski.

NIGHT-SKY SPECTRUM OF VENUS

N. A. Kozyrev, at the Crimean Observatory in Russia, has made an attempt at photographing the emission spectrum of the night sky (dark side) of Venus. Because Venus is so much closer to the sun, its night-sky glow should be about 50 times more intense than the earth's.

According to a note in the *Journal* of the Royal Astronomical Society of Canada, a large number of molecular bands —not all identified—were displayed on a spectrogram obtained with the 50-inch reflector. Some prominent features are attributed to ionized molecular nitrogen.

Two unidentified bands in the ultraviolet may be related to spots such as Ross in 1927 observed near the planet's equator. At the poles, where the temperature is lower, the molecules must have condensed; such spots have not been observed there. In Venus' atmosphere, the unknown molecule may play a similar role to water vapor in the earth's atmosphere.

From the data he obtained, Kozyrev deduces that the outer atmosphere of Venus has a temperature of about −90° centigrade, increasing to about +30° at the surface. The depth of the troposphere on Venus is of the order of 10 kilometers.

EXPANDING UNIVERSE DATA

A survey of all available observational data on the apparent expansion of the universe has been made by N. U. Mayall, Lick Observatory, and A. R. Sandage and M. L. Humason, Mount Wilson and Palomar Observatories. They have used measured red shifts in the spectra of 620 galaxies and in 26 distant clusters of galaxies, obtained by Dr. Humason, combined with red shifts of 300 galaxies measured by Dr. Mayall (114 in common with the Mount Wilson-Palomar list). Apparent magnitudes of most of these galaxies have been determined by E. Pettit. Some description of these programs was given on page 189 of the April, 1954, issue.

They find the value of the Hubble constant, the measure of the rate of apparent expansion, to be 180 kilometers per second per million parsecs, but this is provisional and may be uncertain by 20 per cent. It indicates the age of the expanding universe to be about 5.4 billion years, a value subject to revision after a present four-year program of cosmic-distance measurements is completed.

Data for the very distant galaxy clusters show an apparent departure from a linear expansion, in the direction of a deceleration, but present uncertainties as to the distances of these clusters make this indication inconclusive.

IN THE CURRENT JOURNALS

"EMPTY" SPACE, by H. C. van de Hulst, *Scientific American*, November, 1955. "Space between the stars is not empty. It is occupied by at least two different things: gas, mostly hydrogen, and smoke or dust, consisting of small solid grains."

GALAXIES IN COLLISION

Of the several radio sources interpreted as colliding galaxies, only NGC 1275 in Perseus is large and bright enough for detailed study. Such an investigation has been reported by R. Minkowski, Mount Wilson and Palomar Observatories, to a recent meeting of the National Academy of Sciences.

NGC 1275 consists of two galaxies, an early-type, tightly wound spiral and a highly distorted late-type spiral, with their planes intersecting at an angle of about 20 degrees. North of the nucleus, the late-type galaxy is seen in front of the early-type one. Here the spectrum shows low excitation and double lines, indicating that the late-type galaxy is moving toward the other at a speed of about 3,000 kilometers per second. Near the nucleus and southward, the spectrum shows wide, asymmetric, high-excitation lines, revealing high temperature and much turbulence. These facts suggest that the actual collision is now in progress in the northern part of the system, and has already taken place in the southern part. The total duration of the collision is about one million years.

The position of NGC 1275 for 1950 is $3^h\ 16^m.5$, $+41°\ 20'$. About 0.7 minute of arc in diameter, it has a visual magnitude of 12.5, according to E. Pettit.

AMERICAN ASTRONOMICAL SOCIETY MEETING

On March 21-24, the American Astronomical Society will meet at Ohio State University, in Columbus, Ohio, on invitation of Dr. Geoffrey Keller, Perkins Observatory, and Dr. J. A. Kraus, department of electrical engineering, who operates the Ohio State radio telescope, near Columbus.

The program will feature a panel discussion on "Radio Telescopes, Present and Future," with its chairman Dr. Merle Tuve, Carnegie Institution of Washington. Sessions will be held at the Ohio State Archeological Museum.

The Origin of the Moon's Surface Features—II

HAROLD C. UREY, *Department of Chemistry*
and Enrico Fermi Institute for Nuclear Studies, University of Chicago

Of What Are the Maria Composed?

It is a common assumption that the maria consist of solidified lava which flowed from the moon's interior. Other arguments have been advanced showing that this cannot be true. Terrestrial lavas have temperatures of not over 1,200° centigrade, which is in fact a reasonable estimate of the melting temperature of basaltic liquid in contact with the mantle silicates of the earth. This liquid cannot have a higher temperature because continual melting of the container walls would occur if it did. Flowing out on a cold surface, the lava begins freezing, and on a moderately level surface the advancing wall is fairly high. On the moon it would be even higher because of the low gravity there. Hence, these terminating walls should be visible, but none is observed. This has been pointed out many times, most recently by R. S. Dietz. We have previously concluded that the moon was formed at a low temperature. Also, the high mountain ranges would sink into the moon if it were now or ever had been as plastic as the earth. There is no evidence that this occurred. The conclusion is that the lavas did not come from the moon's interior.

It has been proposed that the melting was caused by the collision energy of the objects falling on the moon. This is a view to which the writer has subscribed. The energy of collision of objects with a 2.4-kilometer velocity amounts to 2,800 joules per gram, and about 2,000 joules are required to heat silicates to their melting points and melt them. Of course, the energy of collision would be expended in sound waves also, but it does seem possible that some melting would occur. (If an object were moving with a supersonic velocity, say 30 kilometers per second, the energy would be sufficient, if dissipated as heat, to volatilize the object completely; whence it should act like an explosive and its material would be blown out of the crater entirely, one would suppose.)

T. Gold has suggested that the maria consist of deep layers of dust which have moved over the surface of the moon in various ways, even from the great land areas to the maria. He believes that heating and cooling of the surface and the effects of ultraviolet light from the sun are producing such dust, and that it is moving over the surface now. He points out that many small lunar craters and the hollows between ridges are filled with this gray material, also that neither lava from the interior nor from collisions seems to be a reasonable explanation for these grayish markings. I am favorably impressed by this suggestion, but would propose for the dust a somewhat modified origin, for which Dr. Gold should not be held responsible.

The Imbrian planetesimal, if spread uniformly over the moon's surface, would make a layer 110 meters deep and, if it contained one per cent of water by weight, would hold sufficient water to cover the moon to a depth of 3.9 meters. The other large planetesimals could have supplied similar amounts of material. Moreover, with reasonable amounts of volatiles, they would explode if they fell with as little as the escape velocity of the moon. Here is a plausible mechanism for the distribution of dust over the moon's surface. After each large planetesimal collision, perhaps a great cloud of dust and water vapor rose above the moon. The dust settled out and the water fell as rain, washed the dust off the mountain peaks into the low places, and sank into the dust and crevices, hydrating the silicates and disappearing.

What evidence can we find to decide such a question as lava flow versus the fall of dust? Lava is a dense, heavy liquid and should push over crater walls in its path and distort the shapes of buried craters. I can find no evidence for this in Oceanus Procellarum and Mare Nubium. The nearly buried crater near Flamsteed is circular in outline, after foreshortening is allowed for. I see no indication of distortion of other craters in this region. But lava must flow downhill, while dust can fall anywhere from an atmosphere. It seems to me that I can see a smooth dust hill over the eastern part of the crater Prinz, and over part of the craters Hippalus and Weiss. Other cases are less clear.

But now how can we account for the irregular shape and black color of Mare Tranquillitatis? One would expect that

In Focus

FACING this page is the first of a series of eight pictures of the moon that will be published consecutively in this volume of *Sky and Telescope*. They will together show the moon in its crescent phases, at ages 4.6 and 24.3 days; this first picture includes the southern tip of the evening crescent.

Each crescent will be presented in four overlapping parts, all to the same scale, so they may be put together to form a mosaic in which the moon's diameter is about two feet. This is smaller than the three-foot diameter of the assembled first- and last-quarter series, with nine parts each, published in *Sky and Telescope* in 1946-47 and now available as Moon Sets.

This series is enlarged from two excellent negatives of the waxing and waning crescents, taken on June 2, 1938, and August 20, 1938, with the 36-inch refractor at Lick Observatory, Mt. Hamilton, Calif. As with Moon Sets, they are among the many well-known lunar photographs made by J. H. Moore and J. F. Chappell with this instrument. The enlargements were kindly supplied by Mr. Chappell.

These current pictures reveal more detail near the moon's edge than can be seen at first and last quarter, for in the crescent phase much of the marginal zone of our satellite is lit by a low sun, allowing even minor hills and ridges to stand out in relief. In the January, 1956, issue a lunar map was published with a finding list for craters and other features, which should aid the reader in identifying the objects in these crescent photographs. South is above and west to the left; this view matches that seen in an inverting telescope.

Particularly noteworthy in this month's feature picture are the Rheita and Borda valleys, mentioned by Dr. Urey last month; the horseshoe-shaped Fracastorius, along the terminator adjoining Mare Nectaris; and the strong shadows of the Pyrenees Mts., to the west of Mare Nectaris in the lower part of the field.

To meet the demand, separate reprints of the January lunar map are available: 1 for 35 cents; 2 for 25 cents each; 50 or more for 20 cents each, all postpaid.

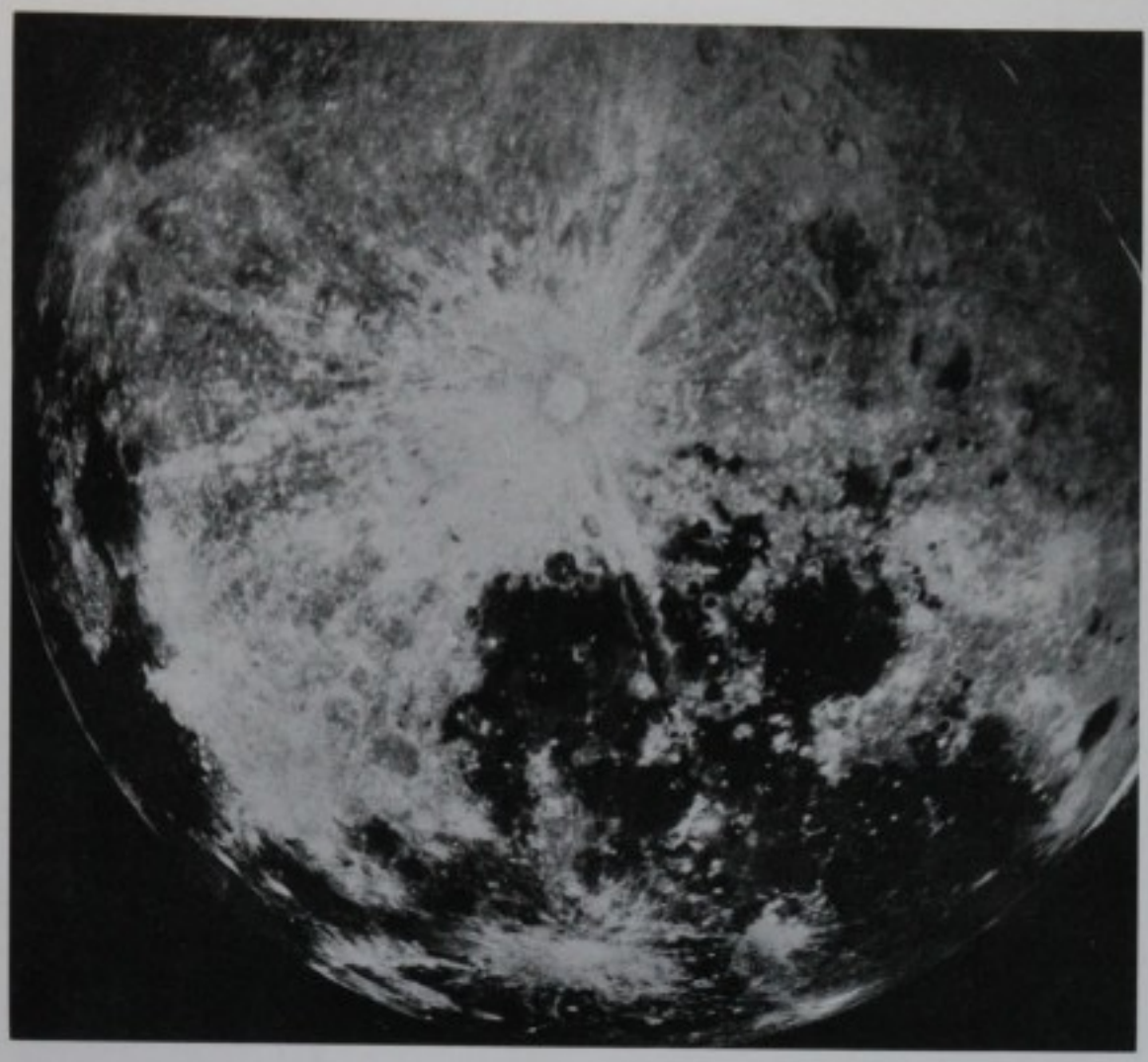


Fig. 3. This picture was made in the same manner as Fig. 2 last month, by means of lunar photographs projected on a globe. Here the region of the crater Tycho is seen as if from a point directly above it. The two rays near the east rim do not pass through the center of the crater at all. University of Chicago photograph.

dust would cover the moon with a uniform color or, at least, that variations of color would be gradual, whereas the boundary of this dark area is sharp and irregular. In fact, Mare Tranquillitatis looks like a lava flow. Some of the craters seem distorted, Ross for example. Also, there are fragments of craters in the western part of the mare.

Perhaps both lava and dust were produced by the collision energy, sometimes one and sometimes the other. Let us try a specific course of events. A large planetesimal fell nearly from the vertical in Mare Serenitatis. It contained little volatile matter and its material was not distributed widely over the moon. It melted and a black lava flowed over the adjoining region of Mare Tranquillitatis. Then the Imbrian planetesimal fell with an appreciable content of volatiles. Dust was spread far over the moon. The hot lava of Mare Tranquillitatis supplied water and hydrogen sulfide which blackened the surface. Or was it some other series of events? This dust hypothesis of Gold, if it stands up to critical study, is to me the most important suggestion in regard to the moon's surface which has been made since the outstanding study of Gilbert in 1893. However, I do not agree with Gold in regard to the source of the dust from light erosion nor with his assumption that the colliding objects were moving with high velocities.

Duration of the Bombardment

One of the most remarkable features of the moon is the absence of large post-mare craters in the collision maria. (In the case of Mare Imbrium this statement applies only to the collision area within the smaller dashed circle of Fig. 2.) Near Mare Nectaris we find Theophilus and Piccolomini, which certainly are post-Mare Nectaris, and others also seem to be the same. These circular collision maria must have been fluid, that is, either dust or liquid, at the time this bombardment stopped. A similar argument applies to the absence of mountainous masses in Mare Serenitatis. If it were formed after Mare Imbrium, the immense collision left remarkably intact the radiating structures of the Imbrian collision in the Haemus Mountains and in the region between the two maria. For this reason, I believe that Mare Serenitatis antedates Mare Imbrium. But then the absence of mountainous masses on Mare Serenitatis similar to the Haemus Mountains means that it was fluid at the time of the Imbrian collision. Liquid would solidify in a short time, say a hundred thousand years or less. Also, dust coagulates, as did the ashes of Pompeii and the mud that covered Herculaneum. The small craters in the maria, which are certainly recent, formed during the last 4½ billion years, show that the dust, if dust it is, coagulated and became rigid. The Straight Wall, which is a fault in Mare Nubium, shows this also.

These arguments lead to the conclusion that the surface of the moon was formed remarkably quickly for the most part. The ray craters and many small craters may be the result of the fall of meteorites over geologic time, but the maria and most of the craters were formed probably within a million years or less. Two explanations occur to me. Either the bombardment was due to a flock of objects passing through the solar system and out again, or this bombardment was part of the terminal stage of the formation of the earth and moon. I subscribe to the latter view.

Meteorites are immensely complicated structures. A worthwhile research program would be to study these objects, try to devise a method of producing imitations of them, and then try to decide what cosmic process might have produced them. It must have been an intense collisional process! It was completed, as shown by the Wasserburg-Hayden potassium-argon dating of meteorites, about 4½ billion years ago.

It is my conclusion that the moon's surface was produced then, and that only minor modifications, due to the fall of high-velocity meteorites and the expulsion of some gases from the interior, have changed its surface since.

This requires an explanation of the sudden termination of the bombardment. If the objects falling on the moon were satellites of the earth-moon system and they were gathered by the earth in a short time, or if only a few of them had orbits extending into the region of the moon's orbit, then a bombardment of the moon for a short interval could be understood. It is difficult to explain this sudden termination of the bombardment if the objects moved in orbits around the sun. This argument agrees with the previous assumption that the objects arrived with about the escape velocity of the moon, 2.4 kilometers per second.

Some Other Features of the Moon's Surface

Certain lunar features, which have been discussed in much detail, seem to me to be of entirely secondary and of superficial importance. The bright rays radiate from certain craters. They cross all features both high and low. They have generally been regarded as dust from crater explosions. In a vacuum each individual dust particle would travel in an elliptical orbit. If a large number of particles originating at a crater moved in similar but not identical orbits, they would fall in a pattern which might or might not be linear. If such particles were moving at 1.7 kilometers per second or faster, and if their paths were initially tangent to the moon, they could travel completely around it. Particles in other orbits would fall on the moon's surface. Thus the two

rays of Tycho (Fig. 3) that do not center on the crater may have been produced by dust which traveled completely around the moon and missed the crater because of the moon's rotation during the nearly two-hour trip. The rays from Copernicus are very irregular, as though some atmosphere were present at the time they were formed (Fig. 4).

One wonders why many well-formed craters, such as Theophilus, do not have prominent ray systems. Were they formed when the moon had a temporary atmosphere perhaps, which would have prevented dust particles from moving in independent orbits for more than meters? Even an object like a modern rifle bullet would be stopped after a few kilometers. Proclus has rays in all directions except over Palus Somnii. This is most puzzling to the writer, and such features that one cannot explain are worthy of thought, for one may learn from a study of them. The lava of Mare Tranquillitatis (if it was lava) spread over the surface, indicating that it was less dense than the materials over which it flowed, but perhaps the region of Palus Somnii floated on the lava. The rays of Proclus which one expects to see on its surface may have been obliterated due to heating and hydrogen sulfide from below.

Or is Mare Tranquillitatis lava from the moon's interior that flowed under a dust layer so that terminal walls are not observed? If so, why is there so much evidence for high rigidity of the moon?

There are volcanic features on the moon, though they do not resemble terrestrial volcanoes. In the smooth area west of Copernicus there is an irregular crack, and along this crack are many small craters. The fall of objects in such a pattern would be most improbable, but the craterlets have very wide openings as compared to their heights; in this they are very unlike terrestrial volcanoes. There are many other similar objects in this region. Very probably analogous craters occur in many other parts of the moon, but are not easily distinguished from collision craters. The great wrinkles in the maria, hundreds of kilometers long, are perhaps waves of lava, or more likely are piles of dust, produced by great slippages of loose dust or mud over the moon's surface, similar to mud flows on the bottoms of terrestrial oceans.

The big valleys have not been considered in this article. The Rheita and Borda valleys are hundreds of kilometers long and the Alpine Valley extends nearly as far. I have subscribed to the view that these were caused by high-velocity nickel-iron objects originating within the planetesimals that formed the collision maria. Others, G. P. Kuiper most recently, believe they are cracks caused by the great collisions. Perhaps this is the correct explanation. They are remarkably straight if they are cracks, and the Rheita Valley has a sharp and prominent bend in it which is difficult to explain if it is due to a missile. But regardless of which explanation is correct, the over-all story of the moon's surface is not changed in an important way. (The writer does not subscribe to Kuiper's completely molten moon theory.)

One could continue to discuss the moon's surface in much detail. It is a fascinating object. It would be wonderful to see the other hemisphere and to have a few samples of lunar surface material.

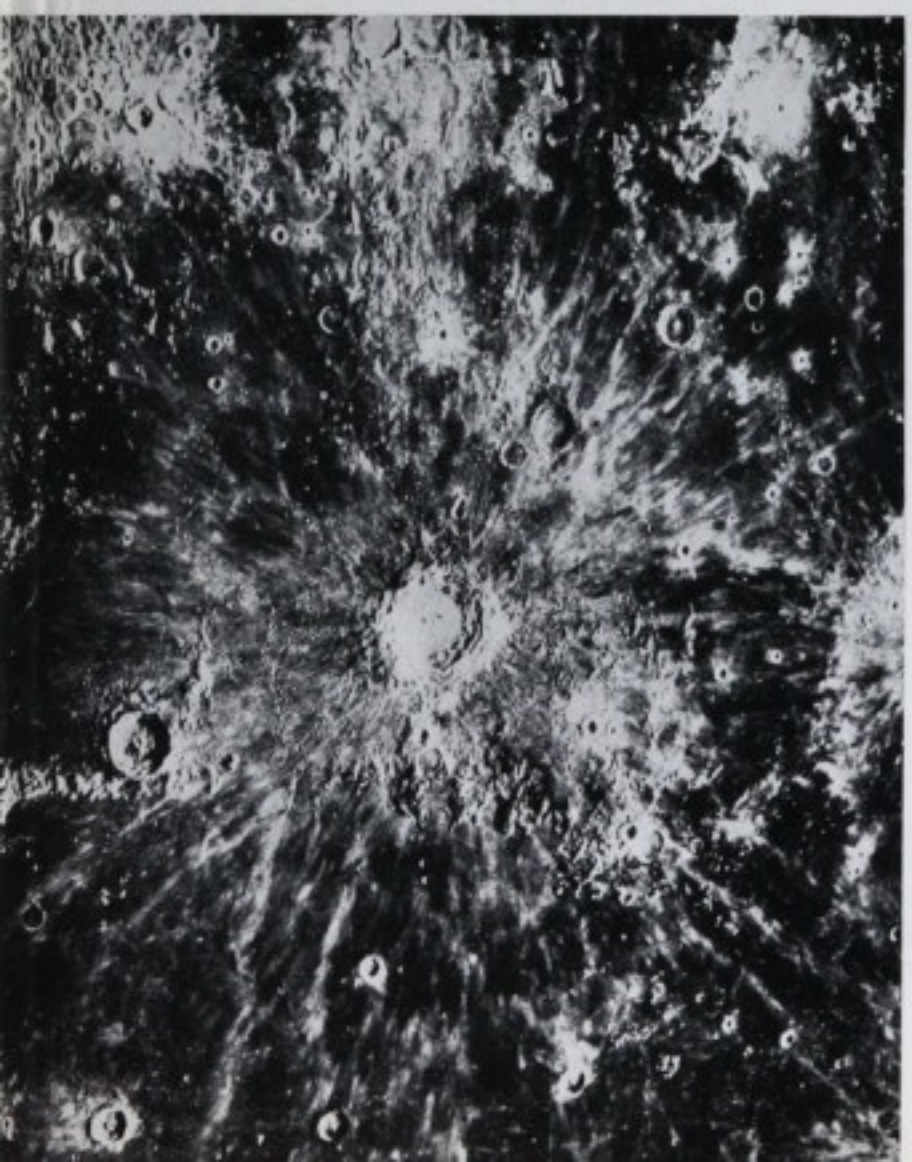


Fig. 4. This high-contrast photograph shows the inner portion of the system of rays and streaks that fan out from the crater Copernicus. South is at the top in this picture, for which the scale is provided by the diameter of Copernicus, 56 miles. The crater Eratosthenes is conspicuous to the left, but seems to have no ray pattern associated with it. It lies on the edge of Mare Imbrium, on the border of the circular area depicted in Fig. 2. Compare the Copernicus ray system with that of Tycho, in the picture opposite.

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A New Southern Hemisphere Observatory

AN EXPEDITION of four astronomers from four countries in western Europe has recently gone to South Africa to seek a suitable site for a large observatory. They are making a year-long study of the general regions of Bloemfontein-Kimberley and Pretoria-Johannesburg.

Plans for such an observatory, to be operated jointly by a group of west European countries particularly interested in galactic and extragalactic research, were first conceived in the summer of 1953, when Dr. W. Baade, Mount Wilson and Palomar Observatories, spent two months at Leiden Observatory.

Our knowledge of the southern hemisphere of the sky is much less advanced than that of its northern counterpart, and it is unlikely that the arrears will be caught up except by a special project like this. Not only does any investigation of the galactic system or the universe require observations around the entire sky, but two key regions for this research—the galactic nucleus and the Magellanic Clouds—are situated in the southern heavens. For both regions, investigations to the faintest observable objects are an essential requirement for progress in our study of the structure of the universe.

A second purpose of the project is to provide first-rate observing facilities for astronomically active countries that lack proper equipment and excellent climatic conditions.

So far, astronomers from the following countries have taken part in discussions concerning the project: Belgium, France, Great Britain, the Netherlands, Sweden, and West Germany. Provisional plans for the observatory include a 120-inch reflector, a 48-72-inch Schmidt telescope (like that on Mount Palomar), and, if possible, a meridian circle.

Although governments and scientific bodies of most of the countries concerned have expressed interest in the program, and funds have been granted for preliminary investigations like site-testing, it is still unknown whether the large project can materialize.

J. H. OORT
Leiden Observatory

Amateur Astronomers

SCHENECTADY OBSERVATORY PROJECT PROGRESSES

Started three years ago, the observatory building of the Schenectady Astronomy Club, Schenectady, N. Y., is nearing completion. The cell for the mirror and other parts are being made.

To swell its observatory fund, the society planned some unusual activities, such as a paper drive, for which a truck and driver were furnished at no cost. Members were asked to contribute papers, rags, and metals, and to get their friends and neighbors to assist. A series of parties, mostly in private homes, is also under way, at which members see slides, play cards, or just visit, each paying 50 cents toward the fund.

WHITTIER, CALIF.

Since its formation last spring, the Whittier Amateur Astronomers Association has been active in observing programs, using six telescopes ranging from a portable 4¼-inch to an 8-inch, f/15 Springfield. Seven new telescopes under construction include a 12½-inch Newtonian-Cassegrain with a 10-inch camera. Plans are being made for intensive observations of Mars during its 1956 opposition.

Meetings are held monthly on the evening of the second Sunday, with subgroups holding special conferences. Amateur astronomers and telescope makers in the area are invited to attend. Gary A. McCue, P. O. Box 531, Whittier, Calif., can supply further information.

DANVILLE, ILL.

Since its organization last spring, the Danville Astronomical Society has increased its membership from five to 14, and has become a junior member organization of the Astronomical League. The club's five adults and nine juniors own six reflectors, two 3½-inch, two 4-inch, a permanently mounted 8-inch belonging to the club president, Robert Kukla, and an unfinished 12½-inch.

The group is looking forward to increased astronomical activity in east-central Illinois, and will appreciate correspondence from other amateurs and from societies. The secretary is David D. Morrison, 5 E. Fairchild St., Danville, Ill.

NEWARK, OHIO

The Newark Astronomical Society held its organizational meeting at the YMCA early in November. With 15 members at the present time, the society hopes for a membership of 25 or 30 in the near future. A recent canvass shows that in Newark there are 13 telescopes, ranging in aperture from 2.4 to 16 inches.

Meetings are to be held the third Saturday of each month at 7:30 p.m. in the Newark YMCA. G. N. Hyder is serving as president, with Robert Dragics vice-president and Ronald Calendine instructor. Gene Cooperrider, secretary-treasurer, can supply further information about the society, and may be reached at 326 N. 11th St., Newark, Ohio.

MIAMI LEAGUE CONVENTION

Dr. Harlow Shapley, former director of Harvard College Observatory, will be the principal speaker at the Astronomical League convention on July 2-5 in Miami, Fla. His main address will be, "The Borders of Astronomy."

Convention headquarters will be at the McAllister, third largest hotel in Florida, at Biscayne Blvd. and Flagler St. The minimum rates are from $5.00 a day single, $7.00 double, and $3.50 each per day in dormitory-type family rooms holding four to eight people. These special rates, a little over half the hotel's advertised prices, will prevail for convention visitors for a week before and after the convention. All public space and guest rooms are air conditioned.

On the local convention committee are E. Downey Funck, general chairman; Arthur P. Smith, Jr., vice-chairman, in charge of program; T. T. Tripp and R. C. Simmons, exhibits; Lynn Burkhart, treasurer; George Norris, transportation; L. Higgins, facilities. Leonard G. Pardue, 641 Falcon Ave., Miami Springs, Fla., is publicity and promotion chairman.

THIS MONTH'S MEETINGS

Cambridge, Mass.: Bond Astronomical Club, 8 p.m., Harvard Observatory. Feb. 2, Charles A. Federer, Jr., Harvard Observatory, "Astronomy in the Service of Man."

Dallas, Tex.: Texas Astronomical Society, 8 p.m., Lone Star Gas Co. auditorium. Feb. 27, John M. Hulme, "The Quantum Theory."

Geneva, Ill.: Fox Valley Astronomical Society, 8 p.m., City Hall. Feb. 14, symposium, Prof. Clarence R. Smith, "Meteors"; Frank Hancock, "Comets and Their Orbits."

Long Beach, Calif.: Excelsior Telescope Club, 8 p.m., home of B. Sproul, 130 5th St., Seal Beach. Alika Herring, "How to Test a Mirror."

New York, N. Y.: Amateur Astronomers Association, 8 p.m., American Museum of Natural History. Feb. 1, Martin Caidin, "The Non-Conquest of Space."

Washington, D. C.: National Capital Astronomers, 8:15 p.m., Commerce Department auditorium. Feb. 4, Francis P. Scott, U. S. Naval Observatory, "The Transit Circle in Present-day Astronomy."

AN ASTRONOMICAL GIFT FROM INDUSTRY

A gift of a complete planetarium for the community high school has recently been accepted by the Ann Arbor, Mich., school board. It will be used as a teaching aid in astronomy, geography, mathematics, and other physical sciences. The installation includes a Spitz projector and a 24-foot-diameter dome with a plastic projection surface.

Argus Cameras, Inc., made the gift through its president, Robert E. Lewis, who said that he and his associates at Argus "desired to do something concrete for the community in which the company operates and in which it has registered its substantial growth in recent years."

GREAT LAKES REGION

The 1956 convention of the Great Lakes Region of the Astronomical League will be held in Indianapolis over the Labor Day weekend, September 1-3. Composed of amateurs from Kentucky, Ohio, Indiana, and the lower peninsula of Michigan, this newly formed region met jointly with the Middle East Region in 1955 (*Sky and Telescope*, December, 1955, page 69). At that time, Charles S. Johnson, 12489 Mendota Ave., Detroit 4, Mich., was elected chairman of the Great Lakes Region.

GREAT PLAINS SOCIETIES

A group of 40 amateurs and professional astronomers met at the Josyln Art Museum in Omaha, Nebr., on December 18th, to organize the Great Plains Astronomical Society. They adopted a constitution and elected the following officers: president, the undersigned; secretary-treasurer, David Solzman, Omaha, Nebr.; corresponding secretary, Milo Mather, Clarksville, Iowa.

The programs of three individual divisions of the society, at Omaha, Des Moines, Iowa, and Topeka, Kans., will be co-ordinated by the GPAS. Each group expects to meet once a month, but every three months one of them will hold a general convention. Thus, each of the 160 interested persons in the Great Plains area will have an opportunity to attend a number of local and regional meetings in a year.

We expect to establish a co-operative observing program, concentrating now on the 1956 opposition of Mars, the 1957 Geophysical Year, meteors, and sunspots. Our observational data are to be published in the *Great Plains Observer*, a new paper for amateurs in this part of the country.

The next general convention of the Great Plains Astronomical Society is scheduled for March, in Topeka.

GEORGE EAGLETON
1422 L St.
Tekamah, Nebr.

Old and Young Star Clusters

OTTO STRUVE
Leuschner Observatory
University of California

One of the finest open star clusters in the northern sky: Messier 67 in Cancer. This area of one square degree is enlarged from a photograph made by Bart J. Bok with the Jewett Schmidt telescope on December 10-11, 1948. The exposure was 90 minutes, on a baked 103a-O (blue) plate. South is upward. Harvard Observatory photograph.

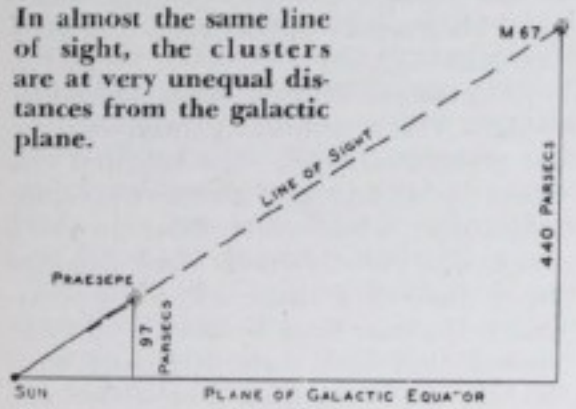
IN THE CONSTELLATION of Cancer are located two conspicuous star clusters, one the well-known Beehive or Praesepe and the other an object of particular interest from the evolutionary point of view. This is Messier 67, or NGC 2682, near Alpha Cancri.

M67 contains about 500 stars between apparent visual magnitudes 10 and 16, and there may be many still fainter stars belonging to it. The earliest spectral type of any star in M67 is close to *A0*; the latest thus far observed is about *K4*, representing reddish giant stars.

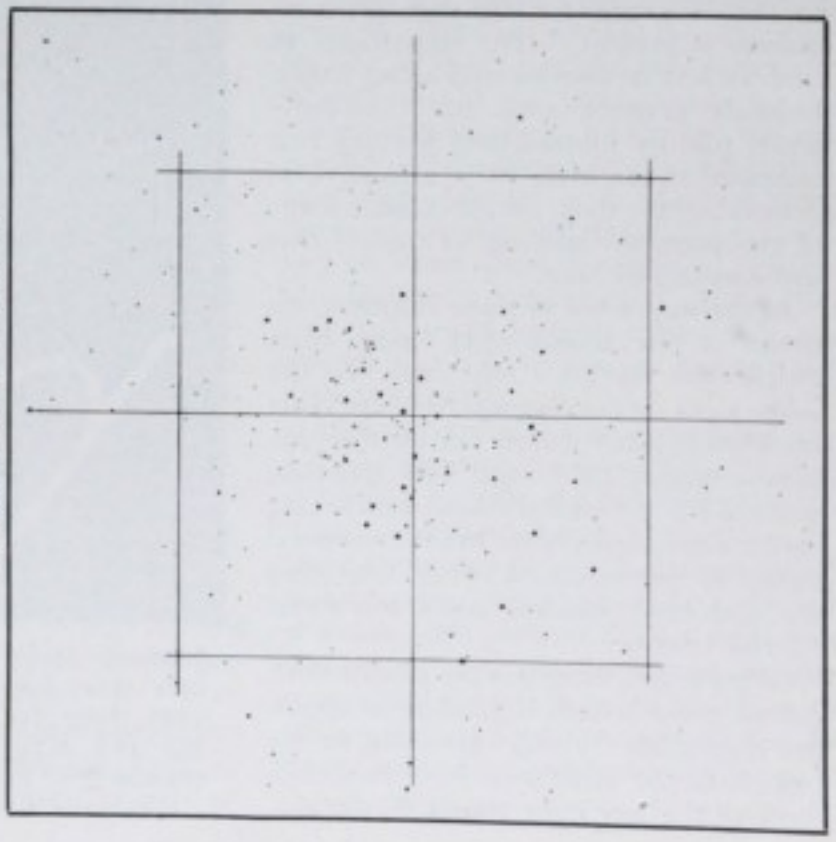
The distance of this cluster is, according to R. J. Trumpler's early value (1930), about 2,400 light-years, but a more recent determination by H. L. Johnson and A. R. Sandage gives 2,600 light-years (800 parsecs, 1955). The Beehive is much closer to us than M67, only 575 light-years away. Although these clusters appear to lie near each other in the sky, one is actually 4½ times farther from us than its apparent neighbor.

As the star chart on page 193 shows, both clusters are a little more than 30 degrees from the central line of the Milky Way. Actually Praesepe is 97 parsecs above the plane, while M67 is fully 440 parsecs, or about 1,450 light-years, above it. Thus, the latter differs from most galactic clusters, for they are found in or near the Milky Way.

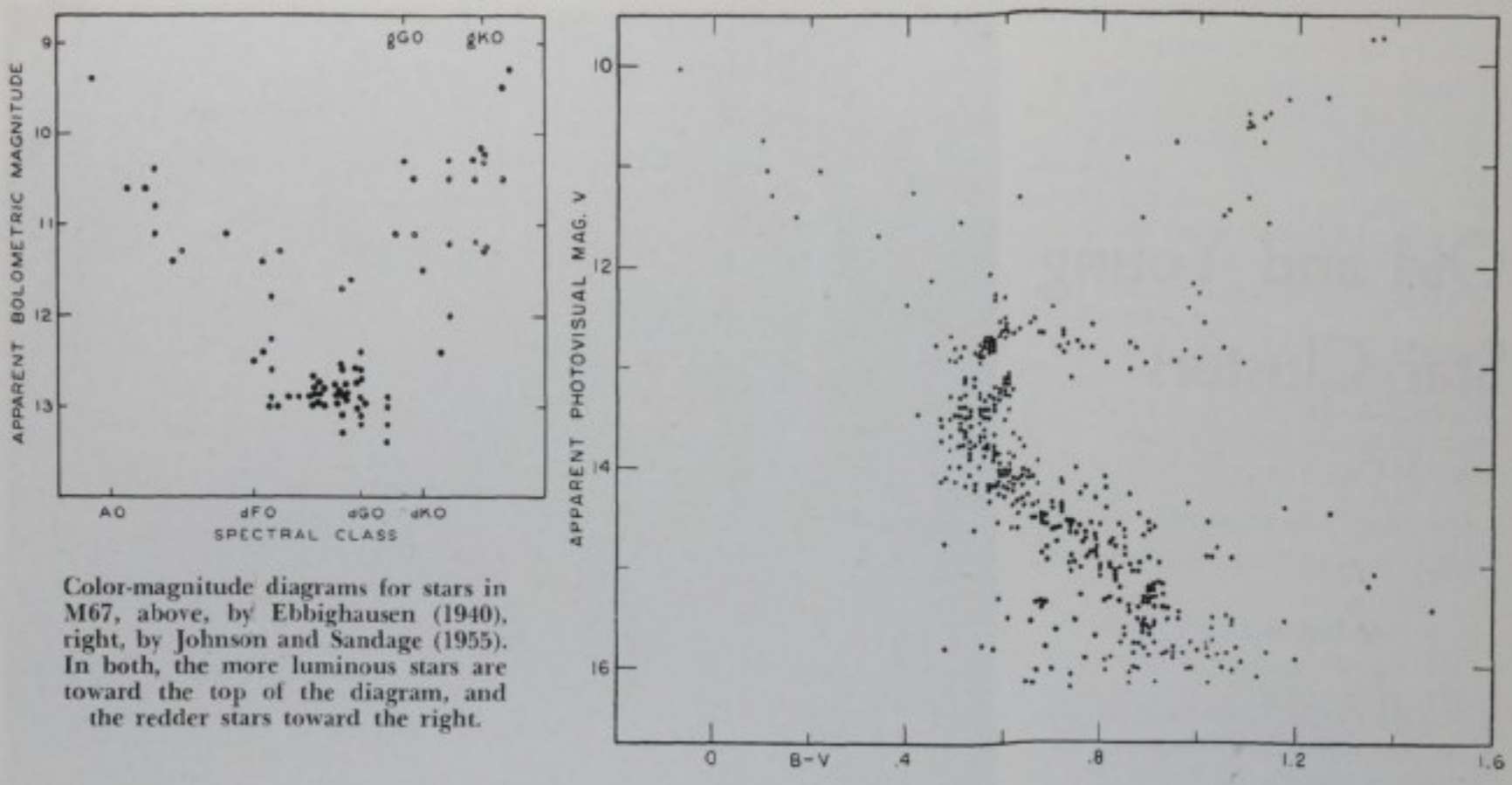
We might then expect M67 to be relatively immune to the tidal and other disturbances that tend to break up galactic clusters lying in the spiral arms of the Milky Way. M67 also contains an unusually large number of stars, and perhaps their mutual attraction aids in preserving its identity over long periods. It appears on a photographic plate as a condensation of bright stars, about 16 minutes of arc in diameter, surrounded by many fainter stars. Some decades ago, H. Shapley had concluded that the bright stars formed merely a well-marked nucleus



In almost the same line of sight, the clusters are at very unequal distances from the galactic plane.



E. Fagerholm drew this map of stars brighter than 14th magnitude in M67, when he made a survey of the cluster at Uppsala Observatory, Sweden, in the year 1906. The co-ordinate lines are 10 minutes of arc apart, and south is upward. The scale is thus 1.2 times that of the photograph above.



Color-magnitude diagrams for stars in M67, above, by Ebbighausen (1940), right, by Johnson and Sandage (1955). In both, the more luminous stars are toward the top of the diagram, and the redder stars toward the right.

of brighter and redder stars in a much larger system, which he estimated might be a degree in diameter.

In 1939, E. Ebbighausen measured the proper motions of the brighter stars of M67 with reference to fainter background stars. He compared four direct photographs, made with the 40-inch refractor of Yerkes Observatory, and corresponding pictures taken 17 to 35 years earlier, to find which stars were cluster members and which were not. He was able to determine the intrinsic brightnesses of the cluster stars and, with spectral types supplied to him by Trumpler, to construct a spectrum-luminosity or Hertzsprung-Russell diagram, which is shown here.

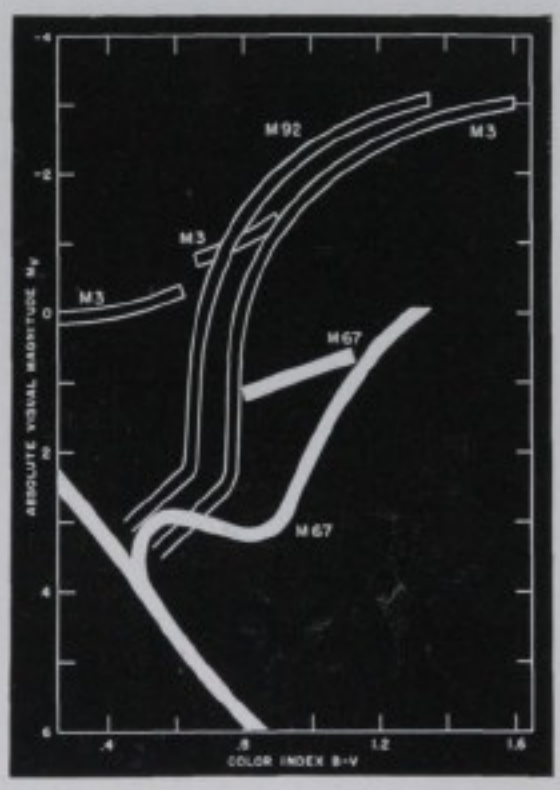
It has been known for many years that the distribution of M67 stars in the H-R diagram "resembles, to a considerable extent, that obtained for globular clusters, in that a prominent late-type giant sequence is present." The importance of this can best be seen by comparing Ebbighausen's diagram with the color-luminosity plot by Johnson and Sandage that appeared in the May, 1955, *Astrophysical Journal*, where those authors discuss many of the problems relating to clusters that will concern us here.

In the upper left of these diagrams, we notice a few bluish stars, some lying roughly on the main sequence. To the lower right in the Johnson-Sandage chart are a great many dwarfs fainter than apparent magnitude 13 and with color indexes of 0.5 and greater; these stars belong on the main sequence, in the same general region as that occupied by the sun (class *G*), and their spectral types are dwarf *F*5 and later.

Of great significance is the pronounced, curved giant branch beginning at apparent magnitude 13 and extending to the right from the main sequence, thence upward to the top right corner of the diagrams. This feature of M67 resembles (but does not exactly match) the giant branches of the globular clusters.

With the cluster's distance of 800 parsecs, the cutoff of the main sequence at apparent magnitude 13 corresponds to a visual absolute magnitude of +3.3. Using this value, Johnson and Sandage have schematically shown in the small diagram how M67 compares with the globular clusters M3 and M92. Finally, in the large chart, they have collected the H-R diagrams for a number of other galactic clusters to show how they differ from M67 and from the globular clusters.

We have seen previously (*Sky and Telescope*, January, 1953, page 63) that the departure of the upper branches of the main sequences of the Double Cluster (h and χ Persei), the Pleiades, the Hyades, and Praesepe, may be interpreted in terms of unequal ages of these clusters. The farther into the region of hot blue stars the main sequence of a cluster extends, the younger it appears to be. Thus, the Double Cluster is youngest of those shown here, while the Pleiades and Hyades are older in that order. On this evidence, the galactic cluster NGC 752 and especially M67 are even older. In fact, their main-sequence cutoffs occur at just about the same place as in M3 and M92. Hence M67 may also be five billion years old, the present estimated age of the globular clusters.



Johnson and Sandage's color-magnitude array for M67 is here compared with those for the globular clusters M3 and M92. The brightest giant stars in M67 are three magnitudes less luminous than in the globulars.

If in its infancy M67 had a fully developed, normal main sequence extending well up into spectral classes *A* and *B*, then its *A* and *B* stars "have long since passed through their evolutionary development and may be present as white dwarfs in an unobservable portion of the diagram." Johnson and Sandage point out that although these hypothetical white dwarfs are too faint to observe readily in M67 and NGC 752, we know that there are a few of them in the Hyades and Praesepe —clusters of intermediate age. But none has been discovered in the Pleiades, one of the younger clusters. A great many white dwarfs may therefore exist in M67 and NGC 752.

As already mentioned, the giant branch of M67 differs noticeably from that of the globular clusters. The brightest red giants in M3 and M92 are near absolute magnitude −3.0, while those in M67 reach only 0.0. Johnson and Sandage argue that these stars are of approximately the same mass, because in all three systems they must have originally been on the main sequence just above the

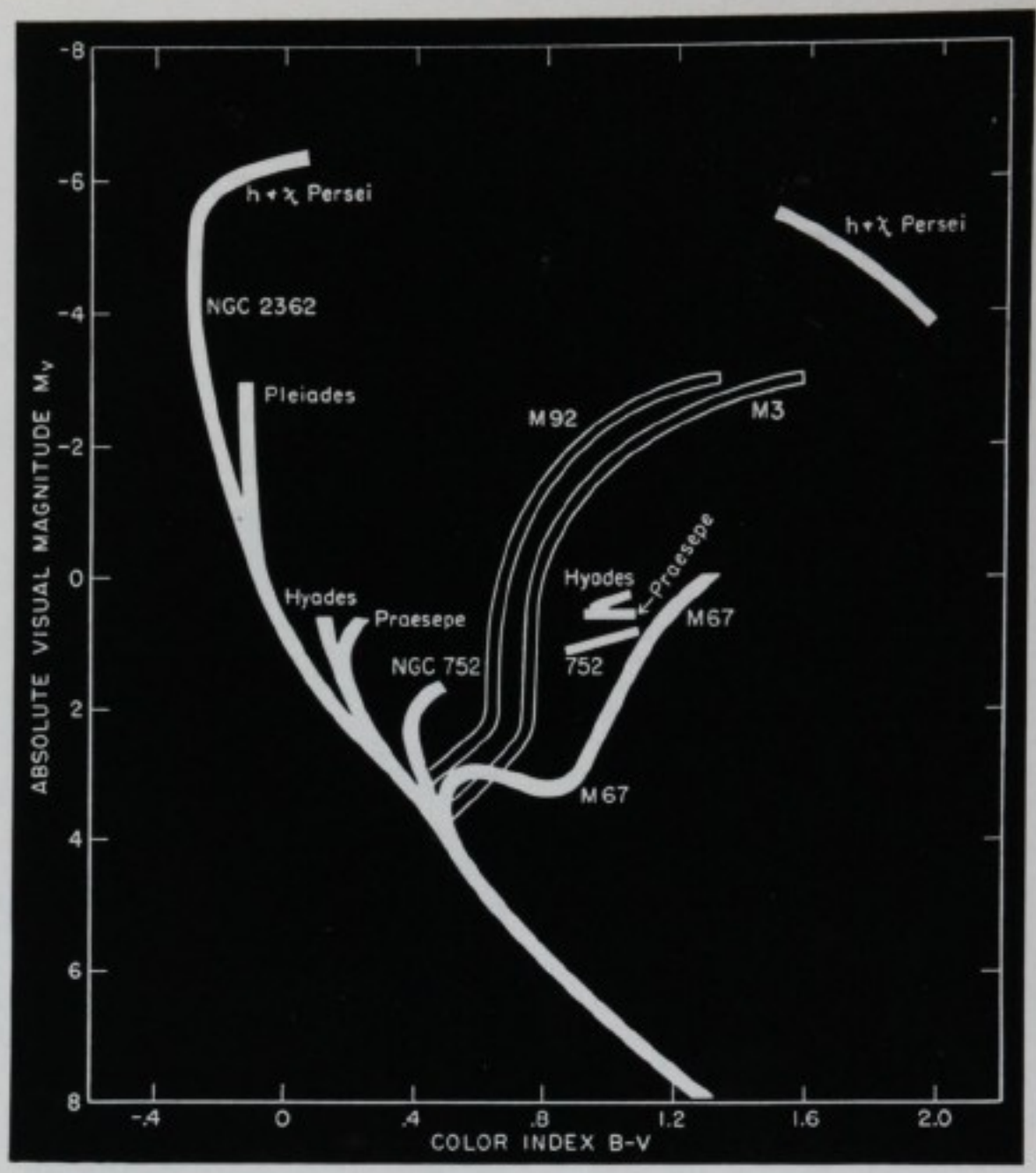
present cutoff at absolute magnitude +3.5.

Hence, these stars evolved along different tracks to their present locations on the giant branches, probably because of an initial difference in chemical constitution. The globular cluster stars originally contained relatively few metallic atoms, but the stars of M67 had a normal cosmical abundance of metals. This idea was confirmed by D. M. Popper, who found that the spectra of the red giants in M67 have normal metallic-line intensities; in M3 and M92 the metallic lines are exceptionally weak, especially in the latter cluster. Presumably the globular clusters were formed in a medium of low metal abundance. M67 and other open clusters originated in a medium which, five billion years ago, already had the same metal abundances as the gaseous nebulae do at the present time.

This conclusion, if confirmed, would weigh heavily against the hypothesis that interstellar matter is gradually being enriched by stars that are forming heavy elements and dispersing them by means of corpuscular radiation, prominences, stellar explosions, and the like. For example, W. Baade has expressed the view that the interstellar medium in the galaxy's spiral arms may always have had its present chemical composition. If so, all stars of the "disk population," old and young, have the same metal abundances as the sun. But the original medium out of which the globular clusters were formed had fewer metal atoms.

Johnson and Sandage call attention to the fact that the giant branches of the Hyades and Praesepe appear almost to intersect those of NGC 752 and M67. This they attribute to differences in the masses of the red giants in relatively young and old clusters, the former having giants of the order of three times the mass of the sun which evolved along almost horizontal evolutionary tracks. In M67, stars three times as massive as the sun have long ago gone through their entire evolutionary development (see Fig. 6, page 66, December, 1955) and have become white dwarfs. Therefore, the presently observed red giants in M67 are much less massive, about 1.2 times the sun, and are evolving slowly, following steeper evolutionary tracks at the present time. In the young clusters, such as the Hyades and Praesepe, these stars are still very close to the original main sequence.

The red giant stars of the solar neighborhood, not associated with clusters, may be either relatively young or they may be as old as or older than the sun. Hence, we might expect them to differ in mass, even though they might resemble each other in spectrum and absolute magnitude, but we lack reliable information regarding the masses of such red giants. Johnson and Sandage point out two cases, however, that may be of significance: The masses of the two components of Capella, according to K. O. Wright, are each about three times the sun's, while those of TW Cancri, from uncertain data by Popper, are 1.3 times the sun's. On the basis of this tentative suggestion, therefore, Capella would be a young system, while TW Cancri would be old.



In this comparison of M67 with six other open star clusters (solid bands), the failure of the main sequences of M67 and NGC 752 to extend into the upper left part of the diagram is an indication of their great age. Diagrams on this and the facing page are from the "Astrophysical Journal."

Another interesting recent advance in our knowledge of stellar evolution comes from the study of a few very young clusters and star associations. Many of these objects contain hot, bright stars that cannot be much older than a few million years. The most luminous members are of class *O*, and have masses of the order of 20 suns. They are now on the main sequence, because their contracting stage of evolution lasts only a few hundred thousand years. But stars of small mass, like the sun, require many millions of years to contract enough to reach the main sequence. Should we not then expect that the *lower* branches of the H-R diagrams of these very young clusters would lie on the right-hand side of the conventional main sequence?

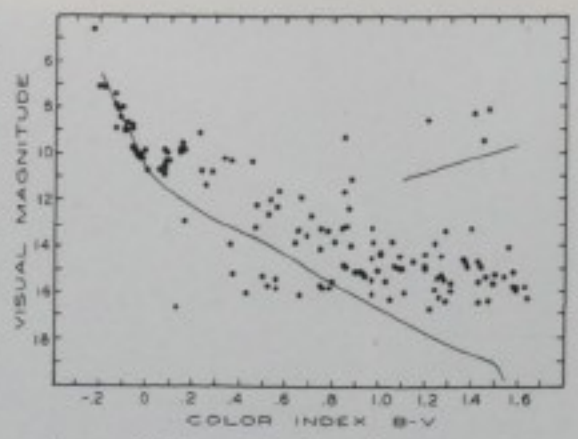
The first indications of such anomalous H-R diagrams came from the work of P. P. Parenago on the cluster of stars associated with the Orion nebula. This is certainly a very young group, for it contains several *O* stars, and its large amount of nebulosity suggests that stars may even now be forming within it. Parenago found that the hotter and therefore more massive stars of this association lie on the conventional main sequence, but the less massive stars—those of approximately solar type—fall above it. Many of these stars are variables of the T Tauri type, and for them there is reason to believe, according to G. Herbig and G. Haro, that they are newly formed, contracting gas spheres which have not yet reached the main sequence.

Additional information concerning very young clusters comes from Merle Walker at Mount Wilson and Palomar Observatories. The open cluster NGC 2264 is located about one hour east of Betelgeuse, almost in the galactic plane, at a distance of about 1,200 parsecs. Walker finds that the hottest and therefore most massive stars in this cluster, from *A*0 to *O*7, lie on the conventional main sequence. But the cooler stars, from *A*0 to about *G* or *K*, depart more and more, as seen in the

diagram. Some 60 of these overluminous (subgiant) stars have been discovered to be variable by Herbig and Walker, and many others may yet be found. Those whose spectra have been obtained show hydrogen emission. They are thus variables of the T Tauri type, a variety of star which Herbig had previously found to lie above the main sequence. Our theory thus seems to hold together pretty well: In the youngest clusters the lower branch of the main sequence is displaced upward, or to the right; in the oldest clusters the upper portion is completely distorted.

Walker points out that there are still many unexplained features among the youngest clusters. A few (for example, the one near Tau Canis Majoris) have only early-type stars. The lower branch of the main sequence is missing. Others seem to contain only late-type stars of the T Tauri variety. Walker suggests that the state of turbulence in the original medium may not always be the same, and that some nebulosities favor the formation of massive stars, while others produce stars of small mass.

It is also possible that the assumption of a uniform age for all members of a young cluster is an oversimplification. If stars can now be formed in the Orion nebula, we might conclude that its early-type stars are a million years or so older than the youngest members. Such a time interval allowed for the process of star formation would be negligible in the case of an old cluster. But in a young one, we might expect that some stars of moderate mass have already run through most of their contracting stage of evolution, while other stars may still be a long way from the main sequence. The displaced main sequence of NGC 2264, according to Walker, has considerable width. This may be due to the existence of stars in this cluster that were formed at somewhat different times. Walker is now engaged in a photoelectric study of several other very young clusters. For one or two of them the data are sufficient to show that they also have displaced main sequences below spectral type *A*0.



A marked peculiarity of very young star clusters is illustrated by M. F. Walker's diagram of magnitudes and colors of stars in NGC 2264. The diagonal curve corresponds to normal main sequence stars. The cluster stars, except for the luminous blue ones plotted in the upper left, tend strongly to be too bright for the main sequence.

The tremendous advances that have been made in the last few years in the study of different types of star clusters form one of the most interesting chapters of contemporary astronomical research. These advances were made possible by the earlier contributions of a great number of individual astronomers, among whom the names of Shapley and Trumpler stand at the very top. Much of their work was exploratory in character, and involved a large amount of routine. The fruits of their labor, which we are now gathering, far surpass their most optimistic expectations.

A Further Note on Image Tubes

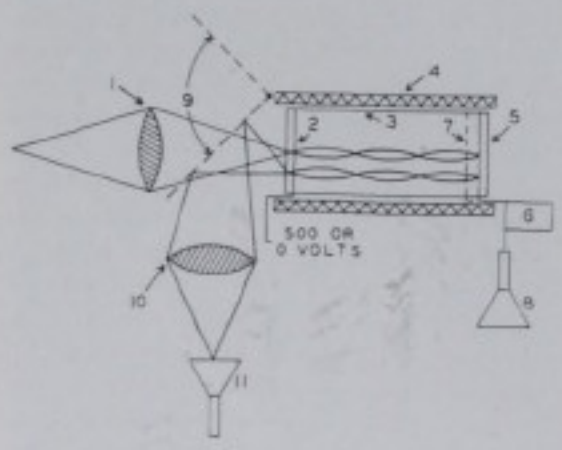
Dr. J. D. McGee, of the Imperial College of Science and Technology, has recently sent me a complete description of the image tube referred to on page 227 in my article in *Sky and Telescope*, April, 1955. The diagram illustrates his design. Its operation is best described in Dr. McGee's own words in the *Journal* of the Royal Society of Arts, March 21, 1952.

"The optical system represented by 1 focuses the light image on the transparent photocathode 2 of the storage tube 3 which is cylindrical and surrounded by a solenoid 4 which produces an axial magnetic field. Electrons liberated by the light of the optical image from the cathode 2 are accelerated by axial electric fields and focused by this axial magnetic field on to a storage target 5 which consists of a thin sheet of mica with a good secondary electron emitting, but insulating, surface on the side struck by the electrons and a conducting signal plate on the other side which is connected to an amplifier 6. In the recording state, these photoelectrons are accelerated to about 500 electron volts energy when they impinge on the target surface, and consequently between 5 and 10 secondary electrons are liberated by each incident primary. These secondary electrons are collected by a suitable electrode 7 and thus a positive charge image is built up on the target surface. This recording process may go on for a long period, possibly hours, since the storage target is a very good insulator and we have quite often stored charge images on such targets for several days without the image becoming weakened or confused by electrical leakage. During this process the amplifier is not used.

"To reproduce the recorded charge image the amplifier 6 is excited and modulates a display cathode ray tube 8. The flying spot of a cathode ray tube 11 on which a normal raster is scanned is focused by means of a lens 10, and a 45° mirror 9, which is moved into place for the purpose, on to the photocathode surface 2, and the accelerating voltages and focusing magnetic field are readjusted to focus the pencil of photoelectrons liberated by this flying spot of light on to the target surface with very nearly zero energy. These electrons will discharge the positive charges stored on the mosaic of the target producing a picture signal which is amplified by the amplifier 6 and displayed on the tube 8. This picture may be photographed or displayed on another storage tube device which maintains the picture for a considerable period.

"It seems quite possible that in the not too distant future electron tubes of this general type may be used for recording very faint optical images as, for example, in large astronomical telescopes."

OTTO STRUVE



This illustrates J. D. McGee's proposal of an electronic device that could be attached to large telescopes for enhancing and recording very faint optical images. Redrawn from the "Journal" of the Royal Society of Arts.

ANNOUNCEMENT

With this issue of *Sky and Telescope*, Helen S. Federer is resigning from her post as managing editor, and for the present the position will remain unfilled.

Trained in literature and languages at Ohio Wesleyan University, Mrs. Federer joined the staff of the Hayden Planetarium in New York City in 1935, where she established the Book Corner, which from its inception was designed to be one of the largest sources of astronomical books of all kinds. She became managing editor of The SKY in January, 1940, and of *Sky and Telescope* with its first number, November, 1941. Much of the over-all quality of this publication has been maintained by her able editorship.

Mrs. Federer has also aided greatly the cause of amateur astronomy and the growth of local societies. During one of its formative years, 1948-49, she was president of the Astronomical League.

C. A. F.

ASTRONOMICAL SCRAPBOOK

The Case of the Lost Trans-Neptunian Planet

THE DISCOVERIES of the planets Uranus, Neptune, and Pluto form some of the most brilliant pages in astronomical history, but there is another side to the record, for there have been other reported findings of new principal planets, some clearly erroneous and at least one still an unsolved puzzle.

Just over a century ago, a flurry of excitement spread across the astronomical world with the report that a tenth principal planet, more distant from the sun than Neptune, had been found at the U. S. Naval Observatory at Washington. Unlike the detection of Neptune a few years earlier, this was a purely accidental discovery and, embarrassingly, the newly found body had already been lost.

James Ferguson, of the Naval Observatory staff, was already well known as an active observer of asteroids. The story began with his apparently routine series of observations of the minor planet Hygiea, which he followed from May to October, 1850, with the 9.6-inch refractor. He was measuring, with a filar micrometer, the location of the asteroid with respect to neighboring stars whose co-ordinates were known. In those days when star catalogues were few and incomplete, it often turned out that the comparison star used could not be found in any catalogue, and hence its position would have to be subsequently determined micrometrically from a near-by catalogue star.

Ferguson's observations of Hygiea were published in the January 18, 1851, issue of the *Astronomical Journal*, and thus came to the attention of J. Russell Hind, one of the outstanding English astronomers of the century, who was then beginning his career as an assistant at the private observatory of Mr. Bishop, in Regent's Park, London. Hind noticed that an anonymous comparison star used by Ferguson on October 21st, and called by him "k," could not be found in the sky.

When this was reported to Lieut. M. F. Maury, director of the Naval Observatory, the peculiar nature of this star came to light. Maury wrote on September 3, 1851:

"The star of comparison with Hygiea on the night of October 21, 1850, has disappeared. It is not now to be found where it then was. Hence I infer that it is probably an unknown planet. . . .

"I directed Mr. Ferguson to examine the proper part of the heavens for the star in question. This he did on the night of August 29, 1851, and reported it to be missing. These circumstances have induced me to have a careful examination made of the observing books of that time. It turns out that this star was observed by Mr. Ferguson with the large Equatorial on the nights of the 16th, 21st, and 22d of October, 1850, and that those observations, had there been sufficient force at the Observatory for their immediate reduction, would then have revealed to us the character of this star."

It was described in the observatory notebooks as of 9th to 10th magnitude, and Lieut. Maury quoted its observed positions as:

1850	R. A.	Dec.
Oct. 16	$19^h\ 17^m\ 40.605^s$	$-20°\ 45'\ 6.58''$
22	19 17 42.364	−20 45 3.42

This is the old 9.6-inch telescope with which Ferguson observed his "planet." Made by the Munich firm of Merz and Mahler, this instrument was erected in 1844, and remained the Naval Observatory's work horse for asteroid and comet observations until the 26-inch Clark refractor came into operation in 1873. It was finally replaced by a 12-inch refractor in 1895. The instrument is pictured from a heliotype in the 1874 volume of the U. S. Naval Observatory's "Astronomical and Meteorological Observations."

The full implications of this report were brought out in Hind's letter of November 13, 1851, to the editor of the *Astronomical Journal*. The only satisfactory explanation, said Hind, was that the object was an unknown planet. The right ascensions on October 16th and 22nd show a change of 1.76 seconds—much too large an error for an experienced observer like Ferguson. The object was moving, and the motion was clearly that of a planet beyond Neptune. If its orbit were circular, then Ferguson's new planet was 137 astronomical units from the sun, and had a period of over 1,600 years, Hind calculated.

But Hind was puzzled, for he had kept this very region under close scrutiny since August, 1847, because of a suspected variable star, and moreover he had been mapping all the stars down to the 11th magnitude in this part of the sky in connection with his own asteroid searches. He was at a loss to imagine why he had not noticed the planet himself, and conjectured that it might vary in brightness.

A year had now elapsed since the only observations of the mysterious object. As its presumed motion was carrying it through the star-rich Milky Way in Sagittarius, its recovery would be a difficult matter at that time when photographic search methods did not exist. Ferguson, with the 9.6-inch Washington telescope, spent nearly four months in laborious but unsuccessful visual search. The supposed planet seemed hopelessly lost, and gradually became generally forgotten.

It was a generation later, in 1879, when the puzzle was unexpectedly and completely solved. The astronomical detective was C. H. F. Peters, who after a colorful career as astronomer, soldier of fortune, and political exile, in Germany, Sicily, and Turkey, had finally become director of Litchfield Observatory at Hamilton College, Clinton, N. Y. There he discovered 47 asteroids between 1862 and 1889.

Peters' explanation was based on the published description of the filar micrometer Ferguson had used. The Washington micrometer contained a metal plate bearing three east-west wires. To measure the difference in declination between two stars, the observer moved the plate until one star was bisected by one of the three wires. Then the other star was bisected by a fourth, movable east-west wire; from the settings of this wire and the movable plate you could compute the declination difference.

It was suggested by Peters that when observing the star "k" Ferguson had erroneously recorded the wire used as No. 1 instead of No. 2. When this correction was made, "k" coincided in position with star 36613 in Lalande's catalogue! Moreover, the discrepancy in the right ascensions was removed too (as the tilt of the north-south wires used in determining them could now be properly allowed for).

This explanation was promptly confirmed in every detail at the Naval Observatory by Asaph Hall. Looking into Ferguson's original records, Hall found that the proper wire had actually been recorded on eight of the 11 occasions in question. For some unknown reason, Ferguson in his reductions had changed all the correct observations to correspond with the three incorrect ones!

This was final and convincing proof that the planet had never existed. Curiously enough, in a catalogue of suspected variable stars published as recently as 1931, you can find Ferguson's "k" listed, with its erroneous position, as a possible variable.

J. A.

AMERICAN ASTRONOMERS REPORT

Here are highlights of some papers presented at the 93rd meeting of the American Astronomical Society at Troy, N. Y., in November. Complete abstracts will appear in the Astronomical Journal.

High-dispersion Prominence and Coronal Spectra

A number of high-dispersion spectra of prominence and coronal emission lines have been obtained with the new coronagraph of the Upper Air Research Observatory, Sacramento Peak, N. M., by Harold Zirin, of the High Altitude Observatory. The advantage in using the coronagraph for prominences is the lessening of scattered light from the sun's photosphere, so fainter prominences and fainter spectral lines become observable.

In the prominence spectra, emission at hydrogen-alpha, hydrogen-beta, and at the D_3 helium line are observed. Their profiles correspond to temperatures ranging from 10,000° to 50,000°, with most of the prominences in moderately active green coronal regions exhibiting temperatures of around 25,000°. This confirms results procured earlier with lower dispersion by Dr. Zirin and D. E. Billings.

Spectra obtained of the green coronal line at 5303 angstroms show minor variations that may be attributed to irregular motions of the source gases. The temperatures obtained by assuming the profile of this line to be produced by pure Doppler broadening range from 1½ million degrees at lower levels to three million degrees in higher regions, where the green radiation is more intense.

Thousands of Suspected Globules

A search has been made on prints of the newly published Palomar Sky Atlas for small roundish dark nebulae, by Robert Fleischer and Peter S. Conti, Rensselaer Polytechnic Institute. On the two blue exposures O-175 centered at galactic longitude 333°, latitude −1°, and O-159 at 337°, +5°, a first survey has revealed not fewer than 10,000 and 7,000 such dark nebulae, respectively.

The diameter on the prints of a typical object of this kind is one millimeter, or about one minute of arc. This is about three times the diameter of the globules marked by B. J. Bok and Edith Reilly in 1947, on photographs of bright nebulae. Nevertheless, Dr. Fleischer believes that these thousands of dark objects seen against the dense field of stars and nebulosity toward the galactic center are also globules of relatively dense dust and gas. Globules may be the forerunners of more compact protostars that are believed to represent stars in the making.

The reality of these suspected globules is plausible in view of a probability of only 1 in 4,000 of finding a one-millimeter circle with no stars in it on a similar plate of randomly distributed stars, and also in view of the improbability of random occurrence of the star formations, rings, loops, and concave wedges that mark the boundaries of the obscured areas. Dr. Fleischer outlined other statistical tests he had applied to show that the large number of globules is real.

Hydrogen-line Broadening in Stellar Spectra

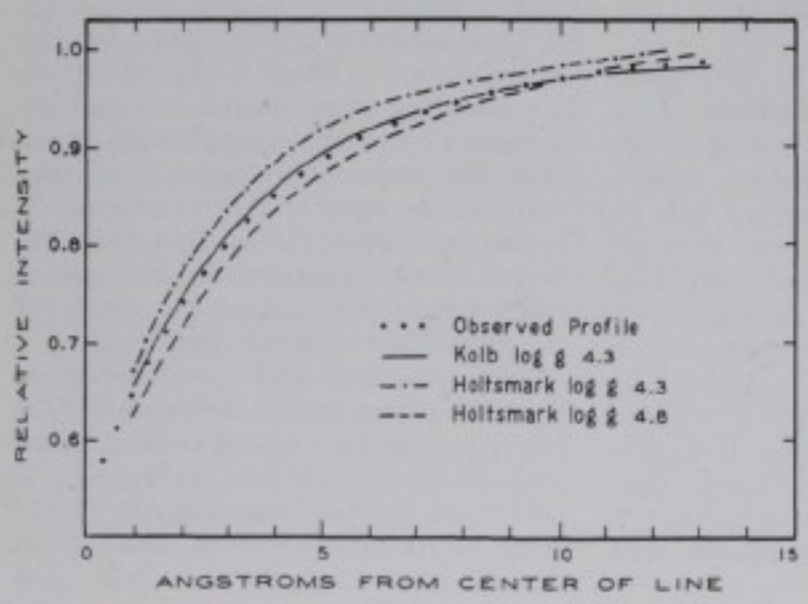
University of Michigan astrophysicists are working theoretically and experimentally on the broadening of lines in stars hotter than the sun, particularly those of spectral class *A*, as described by Lawrence H. Aller in the article, "The Luminous Shock Tube," in *Sky and Telescope* for December, 1954.

There the Michigan astronomer pointed out that the old Holtsmark theory—attributing the broadening only to the disturbing action of nearby ions upon the radiating hydrogen atoms—was inadequate, and that the ions could not be treated as though they were at rest. Many previous workers had supposed the electrons sped so rapidly past the hydrogen atoms that their influence could not be felt.

Comparison of a new theory developed by A. C. Kolb has now been made with the observed profile of the hydrogen-gamma line in the spectrum of the hot star Tau Scorpii (type *B0*, surface temperature about 28,000° absolute). The observations were secured at the Mount Wilson and McDonald observatories, and the results were reported by Dr. Aller, G. Elste, and J. Jugaku, all of the University of Michigan Observatory.

If we suppose that a star is in a steady state under its gravitational attraction upon itself and that the flow of energy through the surface layers is all by radiation, we can compute for a given surface gravity and temperature the changes of pressure and temperature with depth in the star's atmosphere. Such model atmospheres have been calculated by many workers, for instance, G. Traving at Kiel, who used the Holtsmark theory and a surface gravity for Tau Scorpii of 2.3 times that of the sun. This appears to be a much higher value than indicated by similar stars that are members of eclipsing binaries, for which accurate dimensions of the components can be found.

By both the Holtsmark and Kolb theories, Mr. Jugaku has calculated a model atmosphere for Tau Scorpii with a surface gravity about 0.73 that of the sun. The diagram shows the result. Not only is the Kolb theory profile (solid-line curve) broader than the Holtsmark one but the shape is different. The line is deeper in the wings where the influence of the electrons is greater. The shape of the observed profile (dotted) appears to be in better agreement with the Holtsmark curve for the low surface gravity, but the over-all discrepancy is greater. Mr. Jugaku is introducing further refinements in the Kolb theory to make it represent the observations even more accurately.



How closely can the profile of an absorption line in a star's spectrum be predicted by theory? Here three sets of calculations are compared with the observed profile of the hydrogen-gamma line of the B-type star Tau Scorpii. University of Michigan diagram.

Meteors and Rainfall

In 1953, the Australian radio astronomer E. G. Bowen suggested that about 30 days after an active meteor shower there occurs an excessive amount of rainfall at stations all over the world. He proposed that the lag of a month was needed for the fine meteoric material to fall from the upper atmosphere to lower levels where it could provide nuclei for the formation of raindrops.

Now, F. L. Whipple and G. S. Hawkins, Harvard Observatory, point out some serious difficulties with this proposal, chiefly one first suggested by P. M. Millman, of Canada, that even the major annual showers produce only minor additions to the total influx of meteoric ma-

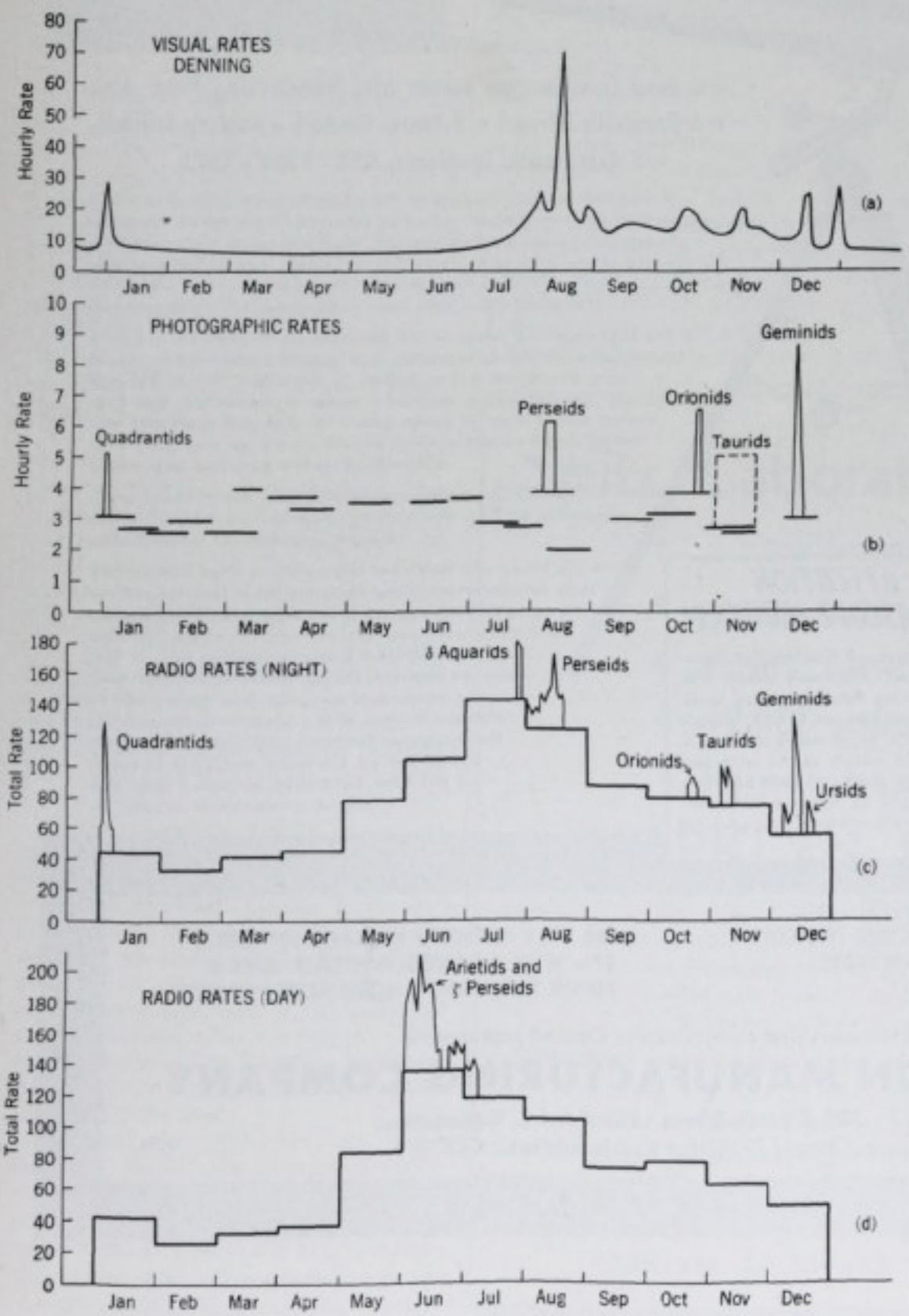
terial into the atmosphere of the earth.

The bulk of the meteoric dust that slowly drifts into the lower atmosphere is debris from sporadic meteors. Evidence for this is found in the accompanying diagrams: photographic and radio counts of meteors both show that showers add only relatively small peaks to the ever-present infall of sporadic meteors. The same conclusion can be drawn from the old visual rates by W. F. Denning, if, as is believed today by some astronomers, the hourly rates of the Perseid meteors in August were exaggerated by Denning.

The great meteor displays that have occurred since modern weather records began were the Bielids, on November 27th in 1872 and 1885, and the Draconids on October 9, 1933, and October 10, 1946. In all four cases hundreds of meteors appeared each minute, yet Drs. Whipple and Hawkins point out that there was no exceptional rainfall 30 days afterward.

There remains the possibility that meteor streams contain very many micro-meteorites—too tiny to be observable even by present radio methods—and that these may act as condensation nuclei, thereby preserving Dr. Bowen's hypothesis. It is hard to explain, however, why micro-meteorites should be present in streams but not among sporadic meteors. The implications of this possibility are being explored.

The original Australian hypothesis also correlated meteor showers with noctilucent clouds. The latter are seen at very great heights in the atmosphere and are believed to be produced by the reflection of sunlight from suspended meteoric debris. Drs. Whipple and Hawkins found no evidence that observed meteor streams produce any changes in the occurrence of the night-shining clouds.



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BOOKS AND THE SKY

RADIO ASTRONOMY

J. L. Pawsey and **R. N. Bracewell.** Oxford University Press, New York, 1955. 361 pages and 23 plates. $8.80.

THE AUTHORS of this book are members of the Radiophysics Laboratory of the (Australian) Commonwealth Scientific and Industrial Research Organization. The "Sydney group" has made substantial contributions to this rapidly growing new science which, as the authors say, not only has permitted the observation of astronomical phenomena that cannot be detected by the optical telescope, but in turn is reacting upon the radio art in fostering the study and improvement of the vital parts of the radio telescope: antenna and receiver.

As the authors point out in their introduction, they "must cater for those who know astronomy but not radio, and also for those who know radio but not astronomy," and so have tried to make the material "readable by anyone with a background of physics." The result is indeed a well-turned-out book. While mathematical formulas are generally elementary, some of them require a knowledge of calculus, and a few differential equations are to be found, yet the reader interested in the contributions of the new science but lacking advanced mathematics will not be seriously handicapped.

One might divide radio astronomy into two parts. The first is expressed by the opening sentence of the preface, that "radio astronomy is built on the discovery that radio waves are reaching the earth from outer space." This part of the science requires only receiving apparatus. The second part employs transmitters as the source of the radio waves and studies the echoes obtained from objects such as meteors, the moon, and perhaps some day the sun and the planets. While the aurora and ionosphere could be included under this concept, they are not treated in this book.

The introductory chapter points out the advantage of radio, in that all but the very shortest waves pass readily through terrestrial clouds and through interstellar dust. Radio astronomy began with the discovery by Jansky, of the Bell Laboratories, in the course of atmospheric radio noise studies, that some of the radiation must be coming from our galaxy. This was followed by the discovery by Southworth, also of Bell Laboratories, of radio waves from the sun.

Observational techniques are next taken up. Planck's law is discussed, which enables radio power to be expressed as a temperature of the source. This is followed by an account of the basic constituents of the radio telescope, the antenna, receiver, calibrating source, and output meter. From optics, the technique of interferometry has been borrowed to improve the resolution of the observations. Two notable interferometers are the Christiansen, involving 32 parabolic reflectors, achieving a resolution of three minutes of arc or 1/10 the solar diameter, and the Mills cross or pencil-beam interferometer.

The authors next consider the theory of radio waves in ionized gases. The magnetic-ionic theory originally devised for propagation of radio waves in the ionosphere is presented, and its application to the study of solar radio waves is discussed. Theoretical aspects of the production of radio waves in the sun or interstellar space are given.

A section on solar physics is followed by one on solar radio waves. At the short wave lengths, the signal is fairly steady, with occasional small bursts. At three centimeters, a day-to-day variation of about 30 per cent sets in. These variations, as well as the bursts, are associated with sunspots. The day-to-day variability increases with wave length. Above 1.5 meters, violent disturbances occur; several types are described, some of which are closely associated with sunspots. Theories of the mechanism of production of solar radio waves are briefly given.

Cosmic radio waves then receive atten-

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tion. Tables summarize the observations of discrete sources at Sydney and at Cambridge, England. Supernova remnants and galaxies of various types are given as sources. In addition to discrete sources, there is general background radiation whose distribution follows the shape of the galaxy. It is conjectured that the continuous spectrum comes from violently agitated interstellar matter. The 21-cm. line comes from cold neutral hydrogen, as is well known to readers of this magazine.

An account of investigations of the surface of the moon by means of thermal radiation is followed by chapters on echo-type investigations of meteors and the moon, and finally a chapter on the effect of the atmosphere on radiation passing through it. A series of excellent photographs brings the book to a close.

It is of interest to compare the present volume with its predecessor, *Radio Astronomy*, by Lovell and Clegg (reviewed in the July, 1952, *Sky and Telescope*). Some important differences are apparent, attributable in part to differences in specialization of the authors.

The Lovell and Clegg book devotes almost 40 per cent to meteors and about 14 per cent to solar studies, whereas Pawsey and Bracewell spend about 25 per cent on solar astronomy and only eight per cent on meteors. In Lovell and Clegg we find a chapter on auroral reflections, and in the present work there are only some passing references in connection with solar phenomena. The newer book, of course, profits by the addition of recent material.

In the chapter on moon echoes, a slip occurs on page 296, in connection with a radar formula. The third line from the bottom should read "smaller" rather than "greater."

The book is very readable, well supplied with references, and is recommended to anyone wishing to learn about this vigorous new branch of astronomy.

PHILIP NEWMAN
Air Force Cambridge Research Center

SOLAR ENERGY RESEARCH

Farrington Daniels and **John A. Duffie**, editors. University of Wisconsin Press, Madison, 1955. 290 pages. $4.00.

IN THE FIRST section of this book, Palmer Putnam points out that while the stored capital of solar energy in fossil fuels will undergo serious depletion in a generation or two, the world-wide daily solar input is still virtually unexploited. Solar energy research is indeed timely.

To the geographical United States, the sun delivers nearly 2,000 times as much energy as is employed here for human purposes; for the land areas of the earth as a whole, the ratio is 8,000 times.

The book is based on the symposium on all phases of the utilization of solar energy held in 1953 by the University of

Wisconsin and sponsored by the National Science Foundation. There are 31 contributors who are experts in their various fields: engineers, chemists, meteorologists, and physicists. Their articles differ considerably in their details of treatment and scientific level of presentation. Some are virtually notes or long abstracts, while others are complete and detailed reports of scientific research.

While a great deal of solid information is included in a very readable form, the brevity of some of the articles makes the book a survey rather than a reference. For people with scientific training, it serves its purpose well—to make known the status of solar energy research as of 1953 and to indicate the needs and initial directions of further work.

The readers of *Sky and Telescope* will probably enjoy most of the discussions. An elementary treatment of the physical and thermodynamic principles inserted after the first two sections might have been helpful for many lay readers. However, the book is not intended for casual reading, and many of the articles give technical details of the principles involved.

It is a striking fact that many of the applications of solar energy have reached similar stages of development. They would be practical in areas of the earth especially favored with sunshine if other sources of energy were too expensive.

Editor Farrington Daniels points out that an acre of glass or concrete, constructed for the collection of solar energy, might cost $10,000. A million acres or 10 billion dollars of capital investment would collect an input of solar energy equal to the present needs of the United States. However, the efficiency of the equipment would be at best a few per cent, and would have to be increased considerably to make such an investment worthwhile.

Among established applications of solar energy are the solar evaporation of sea water (long an industry in some parts of the world) and house heating. George Loef describes a complete solar heating system, while Ralph Morgan discusses the heat pump, of which the household refrigerator is an example. Used in conjunction with solar energy collectors, the heat pump partially solves the problem of heat source and energy sink. K. S. Spiegler details the procedures of the solar evaporation of salt brines to procure fresh water.

The chapters on solar furnaces describe collectors for concentrating sunlight, some containing thousands of mechanically deformed mirrors. Higher temperatures and increased efficiency are now being obtained. Solar furnaces produce very high temperatures for laboratory research today.

It would be helpful to store solar energy in the form of useful fuels. Two sections, photosynthesis and photochemical utilization of solar energy, deal with this

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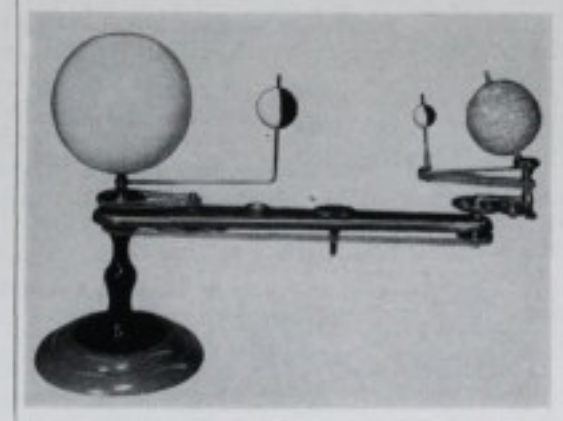

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need. Dr. Daniels considers the possibilities of photosynthesis, and R. L. Meier, of biological cycles. A. W. Fisher, Jr., describes experiments with pilot plants for the production of algae. Photochemical processes are still a long-range possibility.

In the section on atmospheric phenomena and the conversion of solar to electrical energy, various authors discuss energy from wind power, thermocouples with lenses to focus sunlight on their junctions, the photovoltaic cell, and the maximum efficiency of the quantum processes whereby light energy is converted to other forms.

One of the notes in the concluding section, on miscellaneous applications of solar energy, deals with storage of solar energy in the ground. This should be of interest to farmers and gardeners. It is a subject little dealt with elsewhere.

The appendix contains a survey of United States patents pertaining to the utilization of solar energy. There John A. Duffie has compiled a list of some 240 patents, beginning in 1852 with a process for bleaching ivory and ending in 1954 with a solar heat trap. There is an extensive bibliography for each section and a subject index. The book is well filled with figures, diagrams, and tables. The mathematical treatment in many of the papers should make the book particularly useful to specialists.

JOHN WOLBACH
Harvard College Observatory

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OPTICAL GLASSWORKING

This book by F. Twyman, which was reviewed on page 506 of the October, 1955, issue, can only be purchased in the United States from Jarrell-Ash Company, 26 Farwell St., Newtonville 60, Mass. The price is $5.00.

NEW BOOKS RECEIVED

BOLTZMANN'S DISTRIBUTION LAW, *E. A. Guggenheim*, 1955, *Interscience Publishers*. 61 pages. $1.50.

A basic physical principle with considerable significance in astrophysics is discussed mathematically in this little book for advanced students.

DAS FERNROHR FUR JEDERMANN, *Hans Rohr*, 1955, *Rascher Verlag*, Limmatquai 50, Zurich, Switzerland. 182 pages. 8.50 Swiss fr. S.

Written in German for amateur telescope makers, "Everybody's Telescope" gives full instructions for building a small reflector, from the rough grinding of its mirror to the erection of a simple mounting. The book also describes the testing methods used by the active group at Schafthausen, Switzerland.

GUIDE TO THE STARS, *Hector Macpherson*, 1955, *Philosophical Library*. 144 pages. $2.75.

This is the sixth edition of an introduction to the constellations for the beginning amateur. It may be recommended as a short, easy-to-read guide to the naked-eye heavens. Besides photographs and drawings in the text, at the end of the book are simple charts of 18 of the most prominent constellations.

200 MILES UP, *J. Gordon Vaeth*, 2nd edition, 1955, *Ronald Press*. 261 pages. $5.00.

Now in its second edition, *200 Miles Up* tells the adult layman of the progress made so far in the exploration of the upper atmosphere by rockets, the artificial satellite program, and something of other future possibilities. The first edition was reviewed in *Sky and Telescope* for April, 1952.

GEOCHRONOLOGY, *Terah L. Smiley*, editor, 1955, *University of Arizona Press*. 200 pages. $1.50, paper bound.

Papers by 11 Arizona scientists outline different aspects of the problems of dating the earth's crust and its features, by methods ranging from radioactivity to tree rings.

VISTAS IN ASTRONOMY, Vol. 1, *Arthur Beer*, editor, 1955, *Sky Publishing Corp.* 776 pages. $28.00.

No fewer than 215 authors have contributed 192 essays on all aspects of modern astronomy to a two-volume work which is dedicated to Prof. F. J. M. Stratton. The half that has now appeared deals with topics in astronomical organization, the history and philosophy of astronomy, dynamics, theoretical astrophysics, instruments, radio astronomy, and solar physics.

OBSERVATIONAL ASTRONOMY FOR AMATEURS, *J. B. Sidgwick*, 1955, *Macmillan*. 358 pages. $10.00.

A manual for the serious amateur gives detailed and practical information on observing methods covering the sun, moon, planets, comets, and meteors; the aurora and zodiacal light; and variable and double stars. It is a companion volume to the author's *Amateur Astronomer's Handbook*, which deals with instruments and accessories.

THE MOON, *H. P. Wilkins* and *Patrick Moore*, 1955, *Macmillan*. 388 pages. $12.00.

Two British selenographers describe in detail hundreds of the more important craters and other surface features of the moon. The 300-inch lunar map of Dr. Wilkins is reproduced in 29 sections, with recent additions and revisions, on a scale of 16 inches to the moon's diameter. There are many drawings and photographs of lunar formations.

IN THE GREAT
TRADITION

We hope you will be interested in the section of the Questar booklet reprinted on the opposite page. More will follow, and the entire booklet is available upon request.

In this brief historical summary we find it remarkable that within a few years after eighteenth century opticians had mastered the simple reflector, James Short succeeded in making the far more exacting and difficult compound reflector, which even today taxes the skill of the best makers.

The exceptional performance of our own little jewel among telescopes is due to Questar's modern compound optical system, and the very great care with which the instrument is made. The major miracle, that of delivering 7 feet of effective focal length from a mirror of little more than 7 inches focus, is only possible when its maker is willing to discard any mirror that is not some 16 times more exquisite of surface than is required by conventional f/8 reflectors. Then, this 1/64-wave mirror must be matched by just the right correcting lens.

Mr. Short's feelings about his optical wizardry were so strong that he kept his methods secret and caused his tools to be destroyed after his death. We have come to consider the eighteenth century masterpieces of Short and others to be the prototypes and ancestors of Questar. But these prized companions of gentlemen and princes are no rivals to the matchless Questar of today.

For Questar is an amazingly versatile, completely portable, yet powerful telescope that delivers the rock-steady images and smooth automatic following of large observatory instruments. Those who appreciate fine things are apt to fall in love at first sight with a telescope whose smooth controls feel so sweet to the hand, whose short tube does not tremble at the slightest touch, and whose total weight is but a little over 10 pounds.

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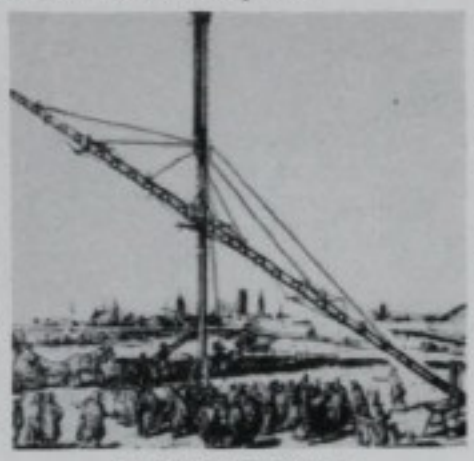
HISTORY OF THE TELESCOPE

The origin of the simple lens appears to be lost in the mists of antiquity. Little is known of its use until spectacles appeared in the thirteenth century and spread throughout Europe during the following three hundred years. That spectacles were used for 300 years before 1608 when the Dutch Van Lippershey used a positive and negative eyeglass lens to make the first telescope, has astonished some historians. The reason was probably that while the simple lens relieved the farsightedness of middle age, it was not until 1575 that the special form of negative lens also required was developed for myopia and hypermetropia.

Galileo's rapid development in 1609 of Lippershey's 3 or 4 power "optic tube" produced the first useful refractor, of some 30 power. For the next 140 years the history of this instrument is the chronicle of attempts to eliminate the colors of the rainbow from the image at the focus of single lenses, for no single lens can bring all colors to one point.

Good glass was hard to make, a three-inch lens being only latterly achieved. To dodge unfocussed color, telescope length became tremendous, resulting in fantastic derricks from which were slung open tube refractors, sometimes 200 feet in length, with a veritable ship's rigging of block and tackle. Incredible labors to keep up with the movement of the stars must have attended each observation, for the heavens seem to be in motion as the earth keeps turning. The diameter of Venus was measured in 1722 by James Bradley with a telescope 212¼ feet long!



Hevelius' 150-foot Telescope

A wholly new way to eliminate color and shorten the telescope was invented by James Gregory, a Scottish mathematician. He proposed a concave parabolic mirror with a central hole, through which focussed rays returning from a smaller concave mirror in front of the first one might pass to an eyepiece behind it. This was in 1663, and five years later the great Sir Isaac Newton made a model of a simpler version of Gregory's system, using a small flat mirror to reflect the cone of rays sidewise out of the tube. In an historic error he declared that a spherical mirror was quite adequate to correctly focus all rays. A similar small model of 6-inch focal length presented in 1672 to the Royal Society is still in existence.

At the court of Louis XIV an artist and sculptor named Guillaume Cassegrain proposed another type of reflector in the same year. In his scheme a perforated primary mirror like Gregory's brought rays to a convex secondary mirror, from which they were reflected back through the hole. By 1672, then, the three principal forms of reflecting telescopes, that still endure, had been invented in a single decade—the simple Newtonian, and the compound Gregorian and Cassegrain forms, the latter shortest of all.

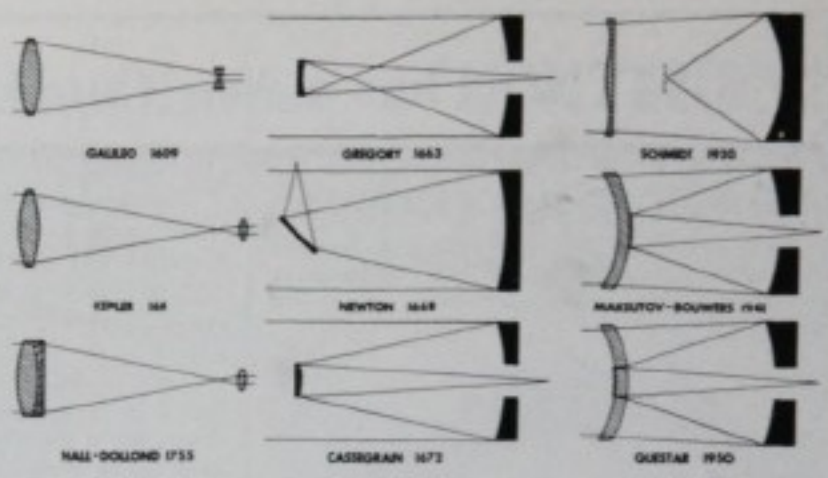
Fifty years were to elapse before any of these could be constructed. Gregory tried everywhere, but no maker with sufficient mastery of the art of polishing mirrors could be found. Then suddenly in 1722 John Hadley submitted an elegant Newtonian reflector of 5 foot focal length, with the then enormous aperture of 6 full inches, to the Royal Society in London. Two astronomers were delegated to test it against the Society's 125-foot refractor. Its performance was sensational. It was relatively portable, with a tasteful mounting and a tube only 6 feet in length. Mr. Hadley was instantly acclaimed, and prospered mightily thereafter.

John Hadley Reflector, 1722

By 1755 the two-lens refractor of Hall and Dollond had achieved a partial solution of the color problem and no longer required a flagpole. It became essentially the refractor of today in size and general appearance, the familiar big spyglass raised on a tripod standing 6 to 8 feet high.

Thus, two centuries ago the basic shapes of refractor and reflector were established. They ushered in the age of great discoveries, and have functioned side by side in friendly rivalry until today. It was to take until the twentieth century before these two would finally be combined.

In this brief summary, we might pause to note an interesting development. In the hands of James Short of Edinburgh after 1722, the compound, reflecting telescope, usually a Gregorian of 3 or 4 inches aperture, had become a powerful compact instrument with normally erect image. The brittle speculum-metal mirrors upon tarnishing after a few months, could only be repolished by a complete refiguring. The exquisite problem of matching two non-spherical curvatures had been mastered as well by other makers at mid-century. A beautiful example of the compound instrument, probably made for Louis XV, is in the Adler Planetarium.



The aperture is 4 inches, length 30½ inches. It is lavishly ornamented in silver, and is supported by a turned column with three curved legs to stand upon a table. The hundred-foot telescope in one short generation had become compressed by skill and ingenuity into an ornamental table-top machine of greater power.

During the rest of the eighteenth century such useful instruments, in the great quickening of interest in astronomy, were to be found not only in the libraries of royalty, but upon the tables of gentlemen of means and education throughout Europe. The difficulty of construction of such Gregorian telescopes may be inferred from the fact that Short's standard price was no less than £500, the price of a splendid town house or country estate in 1745.

The nineteenth century saw Foucault's silver-on-glass discovery of 1857 and the steady increase in size of both types, with reflectors now free to use silvered glass mirrors, which could be recoated without repolishing.

Perhaps first intimations of a merger of the two classical types came in 1895, when Goerz patented a corrected spherical mirror system in which back-silvering made of a lens a mirror too. In 1899 Schupmann showed in a patent application that faults of a big simple lens might be corrected by a small concave mirror.

Short's Equatorial Mount

Then in 1930 Bernhard Schmidt invented the enormously useful combination of spherical mirror corrected by a thin lens, which permits photography of extremely wide star-fields with great speed and perfect sharpness. This Schmidt camera joins lens and mirror into one instrument, the mixed or "catadioptric" form.

The only flaw in this marriage is the non-spherical correcting lens, which is very difficult to manufacture. Bouwers and Maksutov independently in 1941 achieved similar results by means of a much thicker but all-spherical correcting lens.

Questar grew out of these twentieth century discoveries in optics. Its compound system uses a weak negative meniscus to correct the spherical aberration of a perforate spherical primary first-surface mirror. A second-surface Cassegrain secondary mirror is formed by a metallized spot on the front curvature of the lens. Partial correction occurs at the primary and the balance at the secondary, with all the light passing three times through the correcting lens. Questar's triple-passage correcting lens distinguishes it from previous constructions and permits both a slightly shorter design and a fully-protected secondary mirror. With an axial separation of only six inches between lens and mirror, the Cassegrainian optical leverage produces an effective focal length of 42 inches. A negative lens before the eyepiece extends this at will to 84 inches.

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Air turbulence and lack of tranquility at various heights in the atmosphere is the cause of most of this difficulty. Disturbed air makes the stars twinkle, and when we magnify the twinkle we cannot see the star for its apparent acrobatic explosions. Planetary detail becomes obliterated, shimmering in a fuzzy dance.

Questar's short barrel permits an easy demonstration of this phenomenon. If a lighted match is held a few inches below and ahead of the front lens, while some object is being viewed indoors in still air, the refractive power of the warm rarefied gases - TO BE CONTINUED

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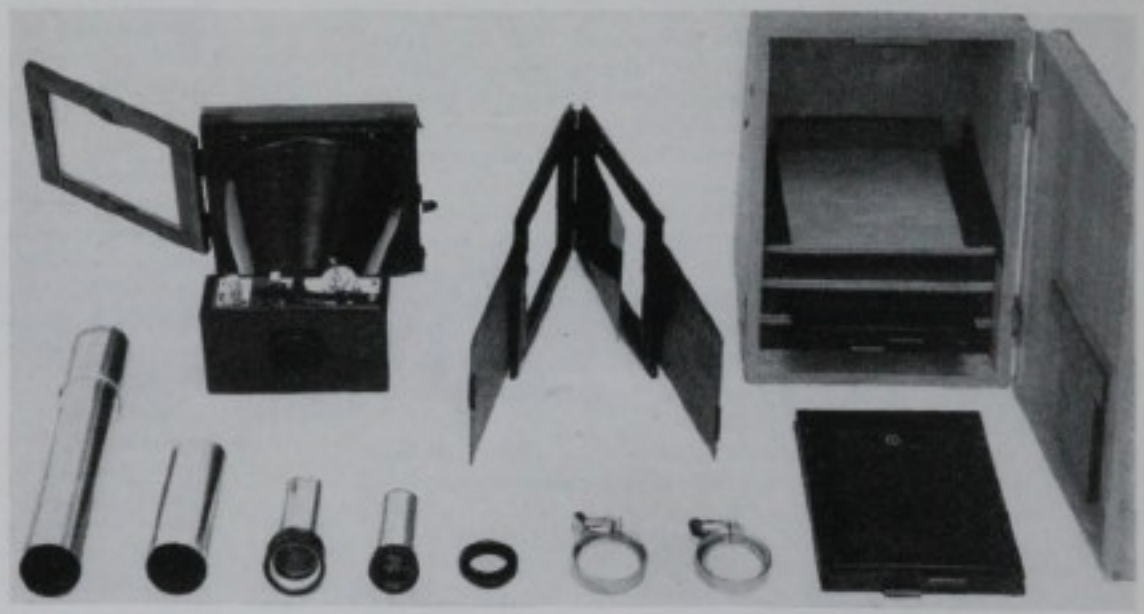
The potential telescope owner is often in doubt as to what he will be able to see with instruments of different apertures. Information of this type is but one of the many interesting features of the new UNITRON catalog. A series of full-page, illustrated articles includes such objects as observing the sun, moon, planets, and deep-sky wonders. Other articles discuss the constellations, give hints on observing, tell how to choose a telescope, and so forth.

Publication of a new catalog was scheduled for this year of 1956 in order to fulfill a prophecy made in 359 B.C. by the Oracle at Delphi in response to a question posed by Eudoxus of Cnidus. Seated on a golden tripod, the Delphic priestess predicted that:

Ἐντὸς τοῦ ἔτους 1956, ἕνας τελείως new UNITRON Catalog θέλει ἐκδοθῇ. Ὁ νέος αὐτὸς κατάλογος θά ὁμιλῇ περὶ τῶν πολλῶν ἐκπληκτικῶν προσόντων τῶν τηλεσκοπίων UNITRON ὡς ἐπίσης καὶ τῆς ἀνωτερότητος τῶν UNITRONS ἐν σχέσει μετὰ τῶν ἄλλων τύπων τηλεσκοπίων. Οἱοσδήποτε ἐνδιαφερόμενος εἰς τὴν ἀστρονομίαν ἐπιθυμεῖ νὰ ἔχῃ ἀντίτυπον τοῦ free UNITRON catalog, μπορεῖ ἁπλούστατα νὰ γράψῃ καὶ θὰ τὸν ἀποκτήσῃ. Ἑπομένως, σᾶς προτρέπομεν ὅπως σπεύσετε νὰ γράψετε ἀμέσως, ζητοῦντες ἀντίτυπον τοῦ new UNITRON catalog τοῦ ἔτους 1956.

The Oracle also predicted that the demand for catalogs would be so tremendous, and the number of names on our mailing list so great, that delays in delivering the catalog to all our friends would be inevitable. Therefore, if your copy has not yet arrived, please be patient. If you have written for our telescope literature on any previous occasion, please do not write again since your name is already on our mailing list and you will receive a copy shortly. With the catalog, we will include a copy of the 1956 Julian Day Calendar which we again printed this year for the American Association of Variable Star Observers. If you have yet to write, please do so at once so that we may reserve a copy of the catalog and calendar for you. Naturally there is no charge for any of this material.



UNIHEX ROTARY EYEPIECE SELECTOR: The old-fashioned method of fumbling with eyepieces in the dark has been outmoded by UNIHEX, UNITRON's new Rotary Eyepiece Selector. With UNIHEX, you always have 6 magnifications ready at your fingertips. To change power, merely rotate a new eyepiece into position while the object stays centered and in focus in the field of view. If through inaccurate tracking you should lose the object under observation, you need only rotate the lowest power eyepiece into position to convert your telescope into a giant view finder, recenter the object in the field of view and rotate back to the higher powers. Model A is designed to fit the UNITRON rack and pinion and is for UNITRONS only. Model B fits 1¼" eyepiece holders. Complete with special clamping device and cabinet.

Model A or B **Only $24.75 postpaid**

SUN PROJECTING SCREEN APPARATUS: White metal screen with matching black metal shade. Chromed brass extension rod with mounting brackets.

Set for 2.4" models **Only $9.75 postpaid**
Set with screen 6" x 6" **Only $13.50 postpaid**
Set with screen 7" x 7" **Only $15.75 postpaid**

ASTRO-CAMERA 220 (Illustrated above): With this camera, owners of altazimuth models can photograph the sun, sunspots, the moon, and solar and lunar eclipses. An equatorial model is required for recording other celestial objects which need longer exposures, and the clock drive is essential for prolonged tracking. The camera uses an air-operated curtain shutter of the Thornton-Pickard type, giving speeds of 1/10 to 1/90 second in addition to bulb and time. The camera may be positioned so that the plane of the film passes through the focal point of the objective, which is then the only optical element. When magnification of the primary image is desired, an eyepiece can be inserted into the camera tube and an image projected on the film. Astro-Camera 220 comes complete with ground-glass back, 3 double plate-holders for 3¼" x 4¼" plates or cut film, a 30-mm. f.l. eyepiece, extension tubes and clamps to lock the camera firmly in place, air-operated bulb release (not illustrated), removable filter, and a fitted wooden cabinet. Model A is designed to fit the UNITRON rack and pinion replacing the customary drawtube and is for UNITRONS only. Model B fits 1¼" eyepiece holders.

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See the back cover.

United Scientific Co. 204-206 MILK STREET, BOSTON 9, MASS.

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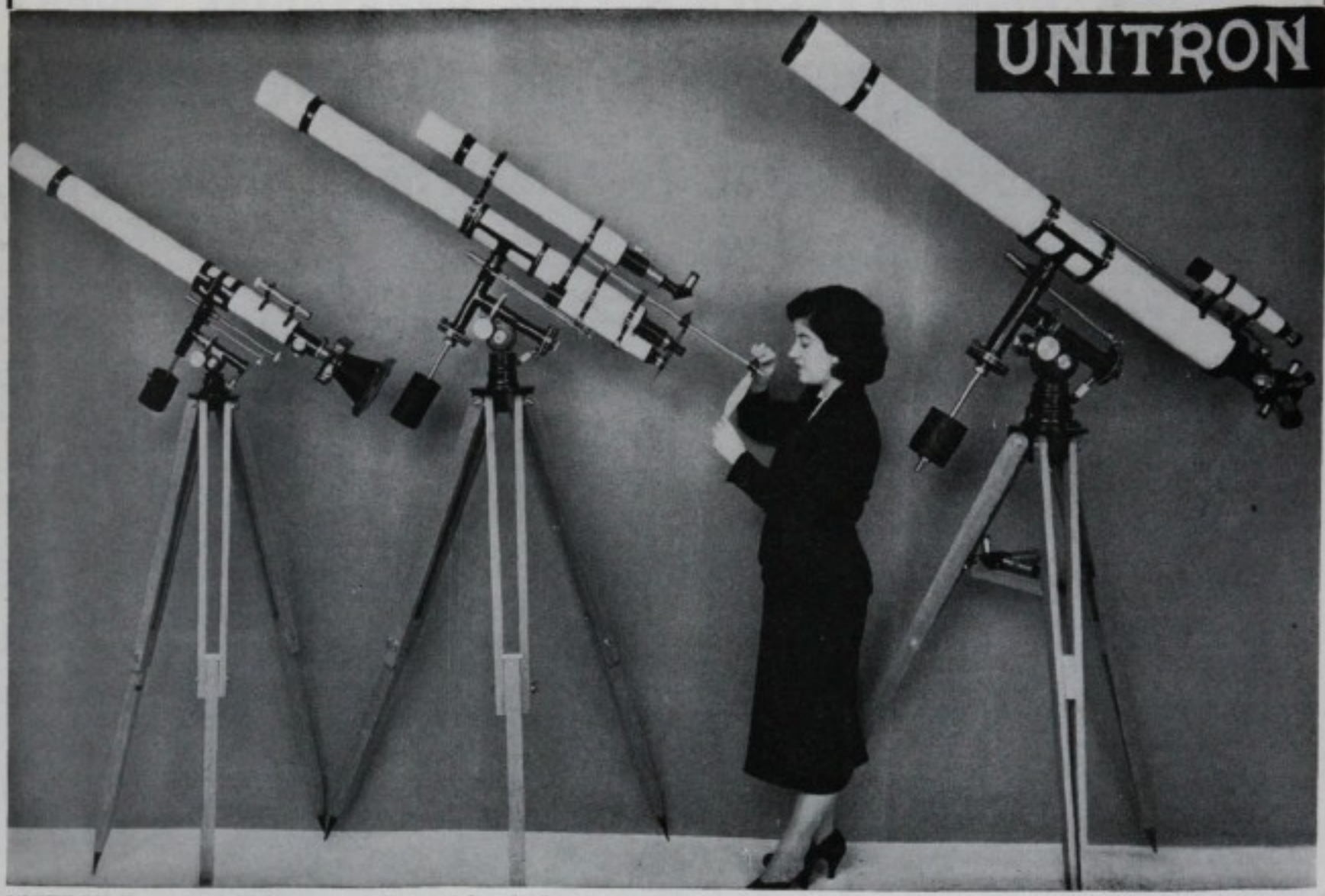

UNITRON Equatorial Refractors: left to right, 2.4" (with astro-camera), 3" Photo-Equatorial (with sun screen), and 4".

Eleven Models To Choose From!

1.6" ALTAZIMUTH ($19 Down) **$75**
with eyepieces for 78x, 56x, 39x

2.4" ALTAZIMUTH ($31 Down) **$125**
with eyepieces for 100x, 72x, 50x, 35x

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3" ALTAZIMUTH ($66 Down) **$265**
with eyepieces for 171x, 131x, 96x, 67x, 48x

3" EQUATORIAL ($108 Down) **$435**
with eyepieces for 200x, 131x, 96x, 67x, 48x

3" PHOTO-EQUATORIAL ($137 Down) **$550**
with eyepieces for 200x, 171x, 131x, 96x, 67x, 48x

4" ALTAZIMUTH ($116 Down) with **$465**
eyepieces for 250x, 214x, 167x, 120x, 83x, 60x

4" EQUATORIAL ($196 Down) with **$785**
eyepieces for 250x, 214x, 167x, 120x, 83x, 60x, 38x

4" PHOTO-EQUATORIAL ($222 Down) **$890**
with eyepieces for 250x, 214x, 167x, 120x, 83x, 60x, 38x

4" PHOTO-EQUATORIAL with clock **$1175**
drive and astro-camera ($294 Down) with eyepieces for 250x, 214x, 167x, 120x, 83x, 60x, 38x, 25x

4" PHOTO-EQUATORIAL with clock **$1280**
drive, fixed pier, astro-camera ($320 Down) with eyepieces for 250x, 214x, 167x, 120x, 83x, 60x, 38x, 25x

Additional eyepieces available for all models.

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- EYEPIECES of the HIGHEST QUALITY: Orthoscopic, Achromatized Symmetrical, Kellner, Huygens. Three to eight eyepieces included with each instrument as standard equipment.
- FINEST MATERIALS throughout. DURALUMINUM TUBE. Moving parts of BRASS carefully machined to close tolerances, and finished in CHROMIUM. No war surplus components used.
- MODERN DESIGN based on time-tested engineering principles. HANDSOME APPEARANCE to which no illustration can do justice.
- EQUATORIAL MODELS have slow-motion controls for *both* declination and right ascension as well as rapid-motion controls. Sturdy TRIPOD.
- ALTAZIMUTH MODELS have slow-motion controls for *both* altitude and azimuth as well as clamps for both co-ordinates. Sturdy TRIPOD.
- VIEW FINDER with crosshair eyepiece.
- RACK-AND-PINION FOCUSING.
- Choice of UNIHEX Rotary Eyepiece Selector or STAR DIAGONAL and ERECTING PRISM for TERRESTRIAL OBSERVATION. The same complete range of terrestrial magnifications as for celestial observation.
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The UNITRON Easy Payment Plan is a convenient and economical way to buy your UNITRON Refractor when you do not want to disturb your savings or when you haven't the total cost of the telescope immediately available. The down payment required is 25%. The balance due is payable over a 12-month period, and there is a 6% carrying charge on the unpaid balance. Your first payment is not due until 30 days after you receive the instrument, and if you should want to pay the entire balance due at that time, the carrying charge is canceled.

There is no "red tape" when you order — you merely fill in the UNITRON Easy Payment Order form, return it to us together with the required down payment, and the model of your choice is shipped to you at once. Whether you buy your UNITRON on the Easy Payment Plan or pay for it all at once, your purchase will bring you a lifetime of trouble-free enjoyment. Far more UNITRONS are sold than any other equivalent telescopes — there must be a reason!

HOW TO ORDER

Send check or money order in full or use our Easy Payment Plan, as described above. Shipments made express collect. Send 20% deposit for C.O.D. shipment. All instruments fully guaranteed.

NEW Higher-Power Eyepieces Available

Accessory orthoscopic eyepieces of 4-mm. and 5-mm. focal lengths are now available for your UNITRON at $14.75 each, postpaid. These give magnifications as follows: 4" models, 375x and 300x; 3" models, 300x and 240x; 2.4" models, 225x and 180x.

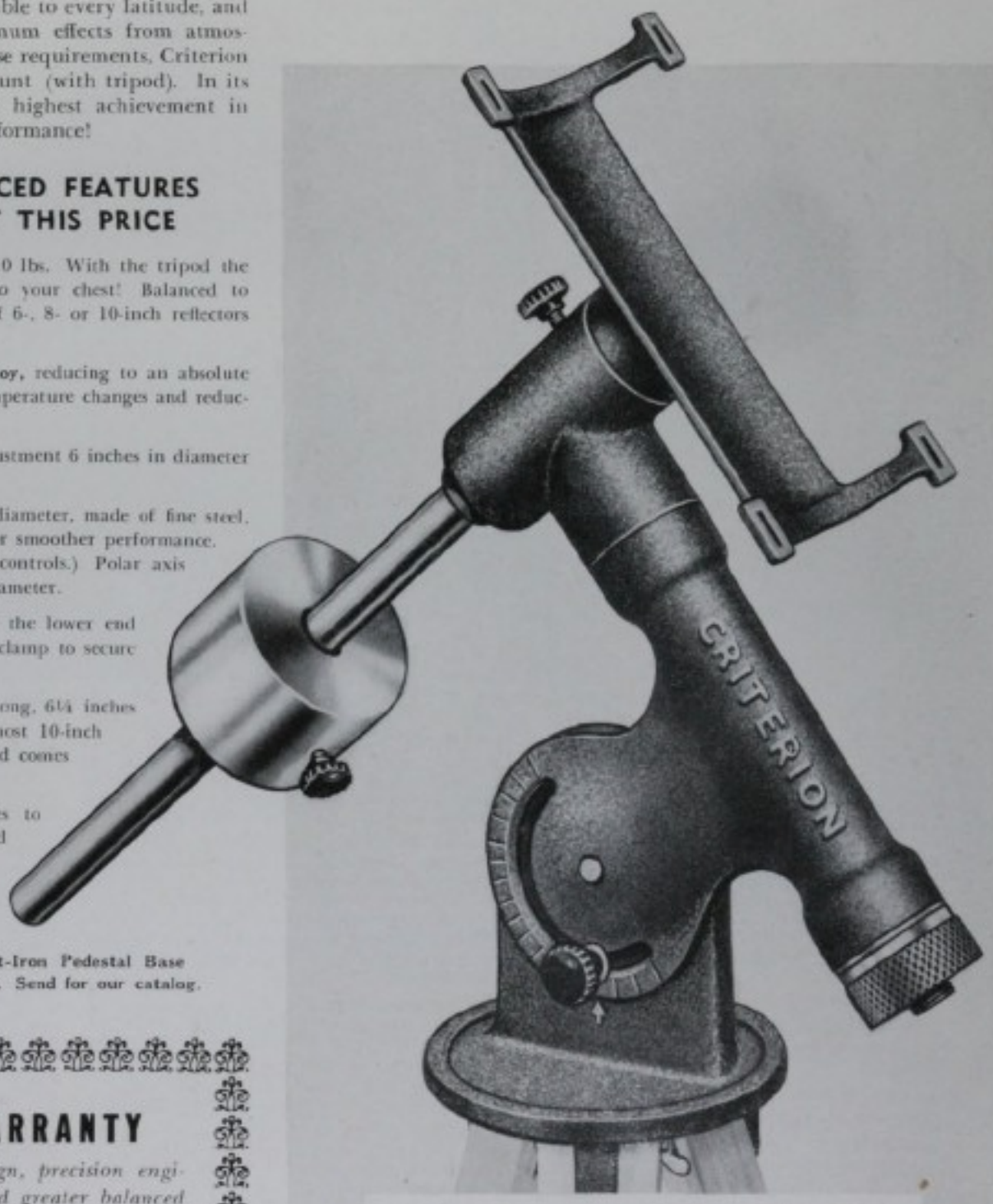
United Scientific Co. 204-206 MILK STREET, BOSTON 9, MASS.

NOW CRITERION DEVELOPS A FINE EQUATORIAL MOUNT FOR 6, 8 & 10 INCH REFLECTORS WITH ADVANCED STABILITY AND RESISTANCE TO ATMOSPHERIC CONDITIONS!

For years observing amateurs and astronomers have been asking for a reasonably priced mounting, adjustable to every latitude, and assuring maximum stability with minimum effects from atmospheric changes. Specifically to meet these requirements, Criterion has developed this fine K6 equatorial mount (with tripod). In its price range the K6 now represents the highest achievement in vibration-free, trouble-free precision performance!

COMPARE THESE ADVANCED FEATURES WITH ANY MOUNT AT THIS PRICE

- Mount weighs 50 lbs. and counterweight 10 lbs. With the tripod the entire mounting reaches from your knees to your chest! Balanced to insure greatest stability with rigid support of 6-, 8- or 10-inch reflectors of conventional focal lengths!
- Major mount parts made of **rigid steel alloy,** reducing to an absolute minimum contraction or expansion due to temperature changes and reducing vibrations.
- Casting contact area about the latitude adjustment 6 inches in diameter —insuring vibration-free action.
- Polar axis is 10 inches long, one inch in diameter, made of fine steel, and precision-fitted to the bearing surfaces for smoother performance. (Keyed to allow adaptation of slow-motion controls.) Polar axis and declination housings are 2½ inches in diameter.
- There is a smooth friction adjustment at the lower end of the polar axis, as well as a positive-acting clamp to secure the scope in declination.
- Base diameter 7 inches. Saddle 11 inches long, 6¼ inches wide. Adaptable to tubes for 6-, 8-, and most 10-inch mirrors. Mounting stands 15 inches high and comes equipped with 22-inch tripod legs.
- Completely machined to closest tolerances to provide perfect fit and smooth action. Finished in black crackled baked enamel.



Motor Drive, Manual Drive, and Cast-Iron Pedestal Base will also be available later at extra cost. Send for our catalog.

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By virtue of its advanced design, precision engineering, superior construction, and greater balanced weight, the new Criterion K6 Equatorial Mount will provide trouble-free performance indefinitely and in any latitude — or your money back. The K6 mount is further guaranteed to outperform any other equivalent mount in its price range.

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GLEANINGS FOR ATM's

EDITED BY EARLE B. BROWN

A Grinding Machine and Some Telescopes

OUR MAILBAG contains some interesting descriptions of unusual telescope designs. This month we call attention to a lightweight 12-inch portable reflector, a tube ventilating system, and the twin telescopes of a Seattle amateur.

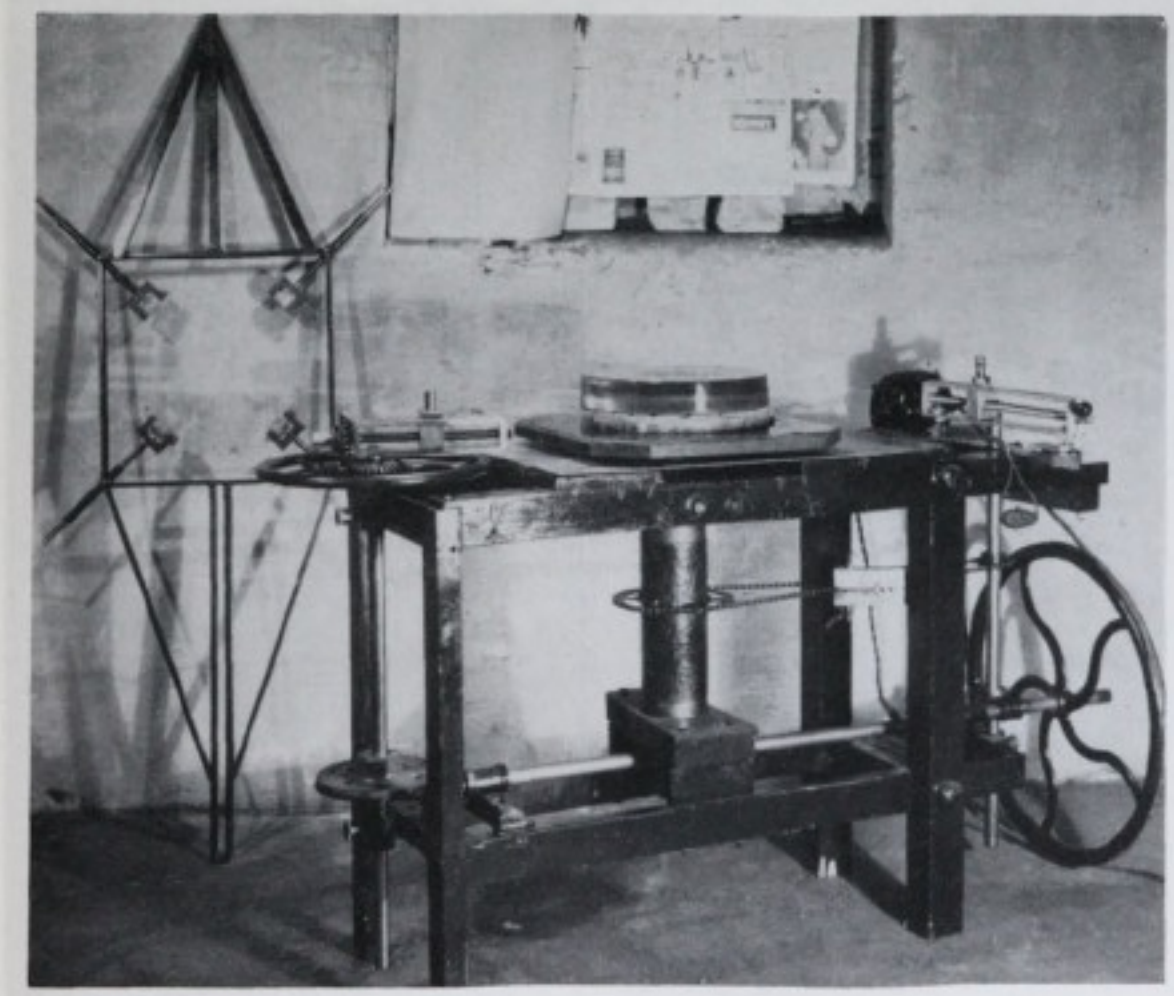
First, however, here is a picture of a grinding machine made by A. M. Donnelly, 5040 Hingston Ave., Montreal 29, Quebec, Canada. An amateur telescope maker since 1934, Mr. Donnelly has made only a 12-inch mirror on this machine, but he writes, "I have one of those 16-inch blanks, and I would like to hear from someone who has experience with a 16-inch Wyldallkirk. Has anyone ever made one?"

Mr. Donnelly's machine follows the general design described by John H. Hindle on pages 235 and 236 of *Amateur Telescope Making, Book One*. The polishing tool is anchored to a rotating table, and the mirror floats freely, face down, upon the tool. The rotation of the mirror is automatic, for over it and the spindles of the machine is placed the framework that is here shown detached at the left, leaning against the wall behind the machine. The mirror is restrained loosely between the sponge-rubber buffers of the framework—as the driving crank moves the latter the mirror is rotated at the end of each stroke.

A PORTABLE 12-INCH

RELATIVELY light weight and easy portability are features of my 12-inch Newtonian. As the picture shows, it is mounted on a system of large-diameter aluminum alloy tubes. The small wheels permit raising one end to push the instrument under shelter in my garage, as well as to nearby star parties of the Peninsula Astronomical Society.

Gusset plates and 5/16" bolts hold the mounting parts together. Extremely strong connections are not required to develop the full rigidity of the members. The polar axle is 5" in diameter, but is of thin (0.040") tubing, and hence is extremely light and more rigid than the customary solid steel axle. The declination axle turns on ball bearings inside a 4" diameter tube which pierces the upper end of the polar axis at right angles. A tight press fit was achieved there with the aid of a paper template, a hacksaw blade, and a round file. The rectangular gusset plates on opposite sides of the polar axis tube restored some of its strength after this operation. Aluminum alloy is ideal for this type



A. M. Donnelly's grinding machine is made from an old battery table, a used washing-machine motor, an old sewing machine, and a very old flywheel. The length of stroke and the overhang are changeable without stopping the machine.

6" Springfield f/8

Aluminum castings from John Pierce. Brass gears, clutches both axes; slow motion and setting circles, cross-hair finder; 4 eyepieces. Excellent optics. Asking *$375.00*. Will prepay shipping.

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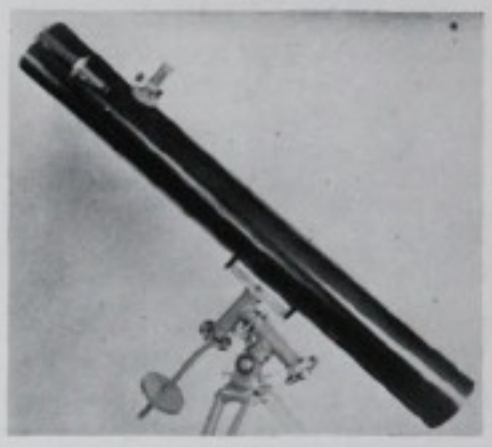
THE NEW GARTHOSCOPE 6-INCH REFLECTOR



- 6-inch Pyrex parabolic mirror correct to ⅛ wave. Aluminized and quartz coated.
- Rack-and-pinion focusing.
- Seamless aluminum tube with baked black enamel.
- Brass setting circles.
- 8x coated achromatic finder.
- Three orthoscopic eyepieces.
- Massive equatorial mounting with slow motion control and tripod (sold separately for $175.00).
- COMPLETE, ONLY **$310.00.** (Without mounting, $150.00)

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Made of light, sturdy aluminum, they furnish an ideal method of securing the mirror to the tube. They are spring adjusted to absorb shocks and cut away for ventilation.

6"-$7.00 8"-$11.50 10"-$35.00

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Takes standard 1¼" O.D. eyepieces. Rack and pinion smoothly machined from solid aluminum castings. Precisely fitted for smooth performance. Main tube is 1¼" long; sliding tube adds 2"; total movement 3¼". Your choice of gray or black crinkle finish.

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Size	*Thickness*	*Price*
4¼"	¾"	$ 5.50
6"	1"	$ 9.50
8"	1½"	$17.00
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You will get the best possible performance from your telescope with one of our clear **fused quartz** diagonals. Accuracy guaranteed 1/20 wave.

Ellipse 1.25" x 1.77" . . $11.00
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Pyrex diagonals, ⅛ wave accuracy.

Ellipse 1.25" x 1.77" . . $ 5.00
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Aluminum coating $1.00 extra.

Send for list of other sizes, quartz mirrors and mirror blanks.

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- Prisms
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Send $1.00 for a comprehensive catalogue, deductible from first $10.00 purchase.

HARRY ROSS

70 West Broadway, New York 7, N. Y.

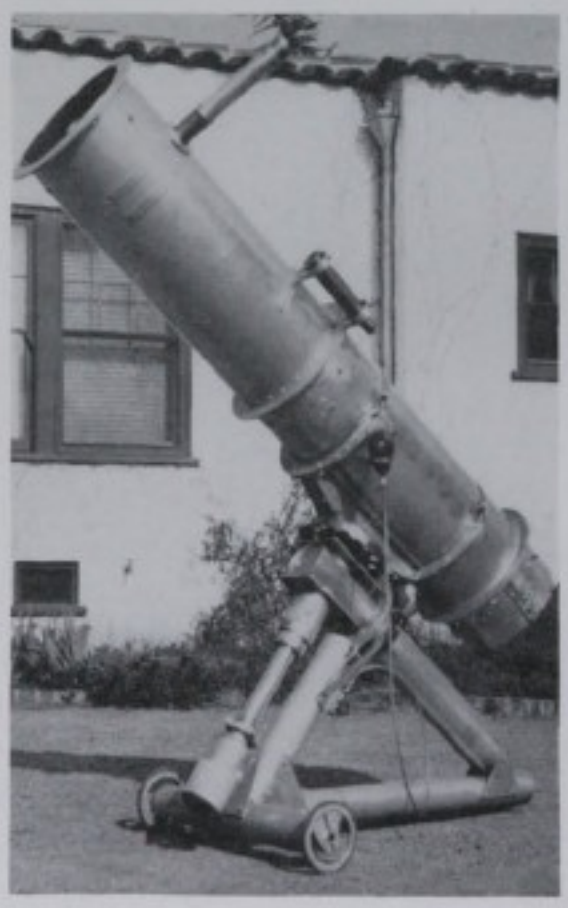
of construction because it is easily worked with simple tools.

The slow-motion control consists of a hand crank adapted from a pilot's radio tuner and a speedometer cable which drives a tangent screw through a worm-gear reduction. The latter is of the type commonly found in war-surplus radio tuners. The tangent screw, which incorporates a spring-loaded half-nut for resetting, was made by sawing up an ordinary C-clamp. This arrangement has proved adequate for visual use.

The main tube is 14" in diameter and was made from 18-gauge 24st aluminum alloy sheet. The three stiffening rings were cast by the local foundry, using a rather simple pattern made from 1/8" thick Masonite. The tube can be rotated to bring the eyepiece into a convenient position for young observers.

The mirror has a focal length of 78", and is used with an aperture of 12". The diagonal flat was cut from a 4" diameter pyrex blank 3/4" thick. I first attempted to make this mirror from a crown glass blank ½" thick, but this suffered from thermal distortion and flexure. With the thick pyrex blank, production of the flat was a straightforward matter.

Especially long eyepiece tubes have been made to carry Barlow lenses. These are 1.6" in diameter, and are placed 4" inside of focus; one amplifies the image 2x, the other 3x. The last provides an effective focal length for the telescope of nearly 20 feet. With the types of glass chosen, it was found that both spherical aberration and coma could be canceled almost exactly, even though the lenses are cemented. When used with a large-diameter Erfle eyepiece, this design pro-



The Jones portable 12-inch reflector.

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Made in America

Optical Instruments including standard Telescopes and all accessories.

First surface flat mirrors of pyrex or crown glass, figured within ⅛ wave tolerance. Uncoated. Thickness about 1/6 diameter. 4½" diam., **$40;** 6", **$65;** 8", **$110.** Larger diameters available.

Parabolic mirrors. Uncoated and hand corrected. Ratio, f/8. 4" diam., **$42.50;** 6", **$58;** 8", **$105.** Other diameters and focal lengths available.

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For the discriminating amateur and the discerning professional.

Our precision optical manufacturing skill has produced an astronomical telescope kit of enviable quality and ease of assembly.

Your name on a post card will bring you our catalog showing our full line of components and accessories. Learn about our mirrors, diagonals, eyepieces, and equatorial mounts. You'll like our OPTENSCOPE. Ask for Catalog T.

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LOW-EXPANSION ELLIPTICAL DIAGONALS

Minor Axis	
¾"	$3.75
1"	3.75
1¼"	5.00
1½"	6.50

MODIFIED RAMSDEN EYEPIECES

½", ¾", 1¼", 2", 3", and 4" focal lengths. Attractively mounted in 1¼" O.D. silicon-aluminum bushings.

VERY FINEST WASHED ROUGE for the final stages of polishing and figuring. In 4 oz. jar (wet) $1.80

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ERFLE, Orthoscopic Quality

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F.L. 16.8 mm. **$14.75** each ppd.

Ocular bodies of machined brass, nickel plated, 1¼ inches in diameter. Optics fully coated and quality is unconditionally guaranteed.

Prices subject to change.

Gailand Company

RETAIL DIVISION, 325 Wyoming Blvd., S. E. Albuquerque, New Mexico

The rectangular gusset plates and details of the spring-loaded slow motion are seen in this picture.

vides an exceptionally wide field of view at high power.

When the telescope was first tried, rather pronounced thermal effects were noticed. Out-of-focus star images had a downward elongation that was not altered by rotating the optical system. Tests with smoke showed a slow current of air, inward along the bottom of the tube and out along the top. Subsequently, six 2" diameter openings were made in the tube directly in front of the mirror. Although the effects are perhaps not completely eliminated, it is interesting to watch the star images become approximately round when these ventilators are opened. In the photograph, the vents are covered by thin plates.

ROBERT T. JONES
840 Lincoln Ave.
Palo Alto, Calif.

TUBE VENTILATION BY SUCTION

TO IMPROVE observing with my 16-inch closed-tube Newtonian reflector, I have installed a system of ventilation that draws air out of the tube, rather than forcing it in with a fan or blower. One advantage of this is that the temperature of the incoming air, at the top of the tube, is not likely to be as variable as that nearer the ground; also, the incoming air will not be as moist.

To avoid the tube walls changing the temperature of air coming down the telescope, I have built in a tubular cloth lining with a fairly tight mesh. This lining tapers from the full diameter of the tube at the top to the mirror diameter at the bottom. The inflowing air passes through the mesh along all its length, producing equilibrium conditions inside the light beam.

As the picture on page 184 shows, the main head of this air is taken by a large manifold from the side of the tube directly in front of the mirror cell.

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Prices for Beral coating telescope mirrors: 3"-$2.25, 4"-$2.75, 5"-$3.00, 6"-$3.50, 7"-$4.00, 8"-$4.50, 9"-$5.50, 10"-$6.50, 11"-$8.50, 12½"-$9.75. Prices for sizes up to 37" diameter on request. Add Postage—Insurance for return shipment.

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NEW MODEL "B", 8-inch **$375.00**

The above are supplied with fiberglass tube, three of the finest orthoscopic oculars giving powers of 72x, 180x, and 315x on MODEL "A", and 84x, 210x, and 360x on MODEL "B".

Clock drive, setting circles, and rotating tube available for above when desired:
Clock drive **$70.00** Circles **$60.00** Rotating Tube **$70.00**

We are now offering a new Richest Field ASTROLA, unmounted, 24" focal length, 6-inch mirror, with 28-mm. ocular. The tube is 26 inches long and the telescope may be cradled in the arms. **$125.00**

Observations of Mars will soon be in order. If you are not satisfied with the performance of your mirror, we will refigure it at a reasonable price.

F/8 parabolic mirrors and elliptical pyrex diagonals, aluminized and quartz coated, corrected to ⅛ wave or better:

6"	**$ 60.00**
8"	**$ 92.50**
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All prices F.O.B. our plant, Long Beach, Calif., and subject to change without notice.

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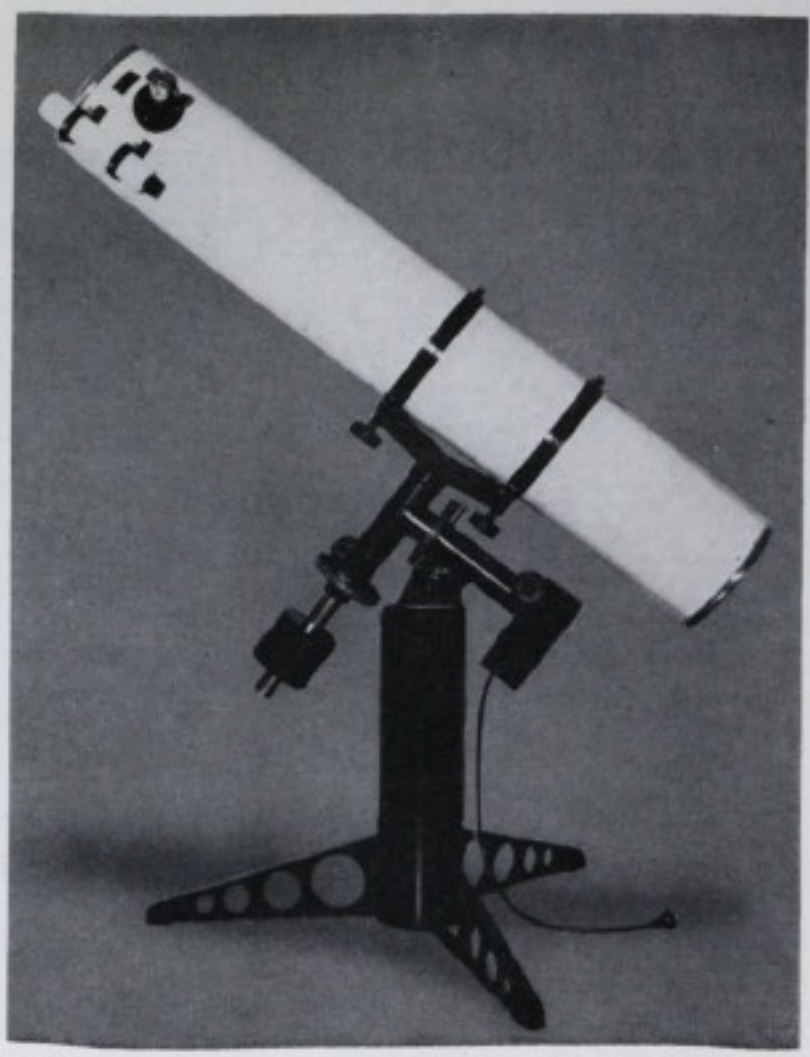
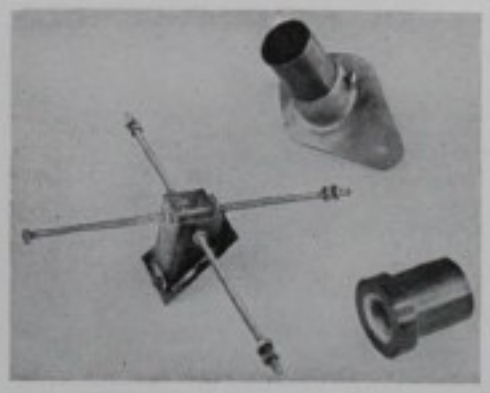
4137 E. Anaheim, Long Beach 4, Calif.



The above is the new De Luxe Model "B", 8-inch, with electric clock drive, setting circles, and rotating tube **$575.00**

TELESCOPE MAKING SUPPLIES



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Long Focus Ramsden Eyepiece. 2 polished plano-convex lenses mounted in plastic tube. Standard 1¼". O.D. 30-mm. e.f.l. **$2.00**

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Diameter	Plate-Glass Tool	Pyrex Tool
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First, the Goodwin Resolving Power lens placed in front of eyepiece gives three times the magnification on each by lengthening your primary focal length angle up to three times, yet extends eyepiece out no more than two inches from normal. This alone sharpens definition.

Next, by achieving your highest powers on more comfortable low-power eyepieces, you lessen image deteriorations due to short-focus acute bending of the convergent beam, since all usual eyepieces are f/1 or less. Again sharper images from this highest precision lens.

Third, you get greater illumination and wider field by relieving tiny aperture restrictions of higher-power eyepieces.

The Resolving Power lens is achromatic, coated, gives flat field sharp to the edge. Here is astonishment! Price $17.50 in 4" long adapter tube fitting standard 1¼" eyepiece holders ONLY (but adaptable to Unitrons only. State if Unitron). Money back if not positively thrilled after two weeks trial! Used and praised by legions!

No COD's—Colleges and Observatories may send purchase order.

FRANK GOODWIN

345 Belden Ave., Chicago 14, Ill.

The mirror cell of the Waale telescope has been lowered several inches to show the ventilating slots around the inside rim of the cell. The main exhaust port is in the tube-end ring above the center of the picture.

A flexible hose is attached here and leads to the pumping apparatus.

In addition, the inner rim of the cell has a continuous circle of wedge-shaped ports through which air can flow from the face of the mirror. The air is also drawn around the mirror to an exit in the center of the cell back. At the bottom of the picture may be seen the hose attachment for this part of the exhaust apparatus.

This ventilating system has given excellent results.

HANS C. WAALE
3080 Pershing Ave.
San Bernardino, Calif.

TWIN TELESCOPES IN SEATTLE

TWO REFLECTORS, one an 8-inch Newtonian and the other a Cassegrainian with an f/4 mirror, are carried on one German-type mounting in my observatory. As the picture shows, the large declination circle and slip-ring hour circle are both lighted. The Cassegrainian is fitted with a round filmholder at the focus. An adjustable film plate makes it possible to reload the holder many times without disturbing the focus.

I have tried out several types of observatory roof, finally deciding upon this one, which has lasted for 10 years and is still as good as new. It is a two-section hip roof, of aluminum; each section is hinged on the side and can be turned over to lie out flat. This gives a full view of the heavens.

My interest in astronomy started when a friend of mine gave me a copy of *Amateur Telescope Making*. It gathered dust for a year before I became interested. After getting some help from other amateurs, I didn't stop grinding and polishing until I had finished three telescopes.

In the picture I am holding a gold cup that was the first prize for a club exhibit at the *Post-Intelligencer* hobby fair in the Seattle civic auditorium last May. It was awarded to the Seattle Astronomical Society, and given to me as president of that group. Our exhibit, which featured telescope making demonstrations, was visited by 35,000 people.

GUY R. BLACKIE
18305 47th St. N.E.
Seattle, Wash.

An observatory 12 feet square houses Guy Blackie's two telescopes, but when the roof is opened they have an unobstructed view of the sky. The Cassegrainian is on the left. Photograph by Eddy Mannery.

"GIANT" 3-inch TELESCOPE

40 power

NEW! JUST OFF THE ASSEMBLY LINE!

Never before has anything like this been offered at so low a price. Here is another example of American ingenuity. Big 3" diameter achromatic coated objective which will give needle-sharp crystal-clear images. Focusing is a delight with the micrometer spiral focusing drawtube. Light-weight aluminum construction throughout, black crackle finish, length open 22 inches, closed 17 inches. This telescope gives an upright image — it is WONDERFUL for astronomy, SUPERB for long distances, EXCELLENT as a spotting scope.

A PERFECT GUIDE TELESCOPE..... Special Price **$57.50**

Aluminum Telescope Tubing

O.D.	I.D.	Price Per Ft.
2⅛"	2¼"	$1.20
3⅜"	3¼"	1.75
4½"	4⅜"	2.75
5"	4⅞"	2.75

All tubing is shipped POSTPAID

Focusing Eyepiece Mounts Rack & Pinion Type

The aluminum body casting is finished in black crackle paint and is machined to fit all our aluminum tubing. Has a chrome-plated brass focusing tube, which accommodates standard 1¼" eyepieces.

For 2⅛" I.D. Tubing	Postpaid	$12.95
For 3¼" I.D. Tubing	"	12.95
For 4⅜" I.D. Tubing	"	12.95

Reflector type for all size tubing.
Complete with diagonal holder..... $ 9.95

Aluminum Lens Cells Black Anodized

Cell for Lenses	Cell Fits Tubing	Price
54 mm Diam.	2¼" O.D.	$ 3.50
78 mm "	3⅜" "	6.50
81 mm "	3⅜" "	6.50
83 mm "	3⅜" "	6.50
110 mm "	4½" "	10.50

MOUNTED EYEPIECES

The buy of a lifetime at a terrific savings to you. Perfect war - surplus lenses mounted in black anodized standard aluminum 1¼" mounts.

F.L.	TYPE	PRICE
12.5 mm (½")	Symmetrical.....	$ 6.00
16 mm (⅝")	Erfle (wide angle)...	12.50
16 mm (⅝")	Triplet.....	12.50
18 mm (¾")	Symmetrical.....	6.00
22 mm (27/32")	Kellner.....	6.00
32 mm (1¼")	Orthoscopic.....	12.50
35 mm (1⅜")	Symmetrical.....	8.00
55 mm (2⅛")	Kellner.....	6.00

The above eyepieces can be supplied **COATED** at 75 cents each extra.

AN ECONOMICAL EYEPIECE

This mounted eyepiece has two perfect fluoride-coated lenses 29 mm in diameter. It is designed to give good eye relief. It has an effective focal length of 1¼" (8x). The eyepiece cell fits a 1¼" tube.... **$4.50**

"GIANT" WIDE-ANGLE EYEPIECE

Known among amateurs as the "Giant Jaegers," this is the finest wide-angle eyepiece ever made. It gives a flat field. It is mounted in a focusing cell. This is an Erfle eyepiece, 1½" effective focal length, with a clear aperture of 2 3/16". It may be used as a Kodachrome viewer, magnifying seven times.

$125.00 Value..... **$18.50**

BRAND NEW COATED 1¼" E.F.L. wide-angle eyepiece. Contains 3 perfect achromats. Aperture is 1 3/16". (Illustrated) **$12.50**

LENS CLEANING TISSUE — Here is a wonderful Gov't. Surplus buy of Lens Paper which was made to the highest Gov't. standards and specifications.

500 sheets size 7½" x 11"..... **$1.00**

"MILLIONS" of Lenses, etc.
Free Catalogue

We pay the POSTAGE — C.O.D.'s you pay postage. Satisfaction guaranteed or money refunded if merchandise returned within 30 days.

JAEGERS DOES IT AGAIN!!

MOUNTED ASTRONOMICAL TELESCOPE OBJECTIVE

Air-spaced — f/15

We offer the lowest priced, hand-corrected, precision, American-made astronomical objective, *mounted in a black anodized aluminum cell.* Our reputation has been established over the years as the most reliable source of high quality astronomical lenses.

"Those in the know" BUY FROM US BECAUSE:

1. Hand-corrected
2. Air-spaced
3. BLACK ANODIZED ALUMINUM CELL
4. Precision Mounted — Ready to Use
5. Color-corrected
6. 3¼" or 4⅛" CLEAR APERTURE f/15
7. 48" or 62" FOCAL LENGTH
8. Quality Can't Be Beat
9. Lowest Price
10. Fully Guaranteed

Each lens is thoroughly tested by us and is guaranteed to resolve two seconds of arc or better. They are corrected for the C and F lines (secondary chromatic aberration). The zonal spherical aberration and the chromatic variation of spherical aberration are negligible. The cell is machined to close tolerances so that it will fit directly over our standard aluminum tubing, eliminating any mounting problems.

3¼" diam., 48" f.l. (uncoated). **$28.00**
Same as above with coating.... **$32.00**
4⅛" diam., 62" f.l. (uncoated). **$60.00**
Same as above with coating..... **$69.00**

We can supply ALUMINUM TUBING for the above lenses.

"BIG" ACHROMATIC TELESCOPE OBJECTIVES

We have the largest selection of diameters and focal lengths in the United States available for immediate delivery. These are perfect magnesium-fluoride coated and cemented Gov't. surplus lenses made of finest crown and flint optical glass. Not mounted. Fully corrected. Tremendous resolving power. They can readily be used with eyepieces of only ¼" focal length, thereby producing high powers. Guaranteed well suited for astronomical telescopes, spotting scopes, and other instruments. Gov't. cost up to $100.

Diameter	Focal Length	Each	Diameter	Focal Length	Each
54 mm (2⅛")	254 mm (10").....	$12.50	83 mm (3¼")	660 mm (26").....	$28.00
54 mm (2⅛")	300 mm (11.8").....	12.50	83 mm (3¼")	711 mm (28").....	28.00
54 mm (2⅛")	330 mm (13").....	12.50	83 mm (3¼")	762 mm (30").....	28.00
54 mm (2⅛")	390 mm (15.4").....	9.75	83 mm (3¼")	876 mm (34½").....	28.00
54 mm (2⅛")	508 mm (20").....	12.50	83 mm (3¼")	1016 mm (40").....	30.00
54 mm (2⅛")	600 mm (23½").....	12.50	102 mm (4")	876 mm (34½").....	60.00
54 mm (2⅛")	762 mm (30").....	12.50	108 mm (4¼")	914 mm (36").....	60.00
54 mm (2⅛")	1016 mm (40").....	12.50	110 mm (4⅜")*	1069 mm (42 1/16")	60.00
78 mm (3 1/16")	381 mm (15").....	21.00	110 mm (4⅜")	1069 mm (42 1/16")	67.00
80 mm (3⅛")	495 mm (19½").....	28.00	128 mm (5⅛")*	628 mm (24¾").....	75.00
81 mm (3 3/16")	622 mm (24½").....	22.50	128 mm (5⅛")	628 mm (24¾").....	85.00

*Not coated

● We can supply ALUMINUM TUBING for the above lenses. ●

A. JAEGERS

6015 Merrick Road
LYNBROOK, N. Y.

BUILD YOUR OWN
3" REFLECTING TELESCOPE
with this
COMPLETE, 87-PIECE
Do-It-Yourself KIT!

Complete parts—no machining—easily assembled; a nine-year-o'd can do it! All nuts and bolts supplied. Nothing extra to buy. Kit includes 3" spherical mirror 30" F.L., aluminized and overcoated. Guaranteed to resolve detail right up to theoretical limit. Tripod 40" high with cast-iron tripod head, all holes drilled and tapped (all machining finished). Other parts made from ¼" thick steel all ready to assemble. Smoothly functioning equatorial mounting. Locks on both polar and declination axes. Polar axis at 40°; latitude adjustment made with tripod legs. Natural grain finished hardwood tripod legs. Heavy wall black kraft telescope tube with special black glare-reducing liner. Eyepiece mount has slide focus adjustment. Mirror attaches on new type mounting with pressure-sensitive adhesive tape eliminating distortions. Mirror is ventilated. 60X eyepiece and a 100X Barlow lens included. 90X and 120X eyepieces avai'able at extra cost. Crosshair finder parts included with mountings. Parts zinc plated to prevent rust. A real kit in every respect. Can also be used terrestrially. Nothing extra to buy. Directions inc'uded! Money back guarantee.

Stock #85,025-Y ..... $29.50 f.o.b.

SPECIAL NOTICE

We Are Liquidating a Huge, Newly Acquired Stock of U. S. Gov't. Telescopes . . .

Your Chance to Pick Up an Excellent Bargain

READ THE DETAILS CAREFULLY — THEN BUY!

M-17 8-POWER ELBOW TELESCOPE

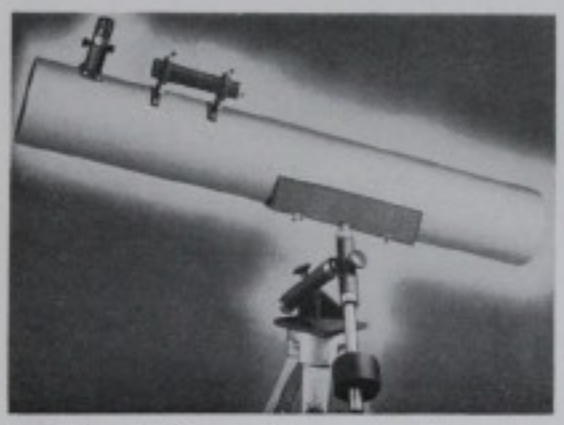
$200 VALUE FOR ONLY $12.50 POSTPAID

BIG 2" OBJECTIVE—KELLNER EYEPIECE—AMICI ERECTING PRISM
4 BUILT-IN FILTERS—RETICLE ILLUMINATION

This is Edmund's biggest bargain offer in an entire decade. Weight of this instrument is 5 pounds. Field is 6°, exit pupil is 0.243 inch. Excellent for finder on an astronomical telescope. Ideal for use as a mounted telescope for terrestrial observation. Also can be used for telephoto photography. Objective lens can be removed and a tube added with a longer focal length objective to convert to a high-power astronomical telescope. The focusing 28-mm. F.L. eyepiece alone is worth more than $12.50. These telescopes were designed for spotting airplanes in the sky and have excellent resolving power and definition. The image is sparkling clear and bright — will delight you. Adjustable focus from 15 feet to infinity. These instruments are in good condition — practically new. You can buy this exceptional bargain with absolute confidence. In accordance with the policy prevailing on all Edmund merchandise, we guarantee complete satisfaction or your money back.

Stock #70,065-Y ..... $12.50 ppd.

EXCEPTIONAL BUY IN A
Complete, Assembled
6" REFLECTING TELESCOPE
40X, 60X, 120X, 150X, 300X



Complete with heavy duty equatorial mounting and tripod. Tripod has cast aluminum head and rugged wooden legs for stability. (Folds for storage.) Equatorial mount has 1" diameter shafts with Boston bronze bearings. 5-lb. counterweight for perfect balance. Locks on both declination and polar axes. Polar axis set at 40°; latitude adjustment made with triped legs. Black crinkle finish on mount. Telescope tube made of aluminum; white enamel finish on outside. Rack-and-pinion focusing eyepiece mount. 7X achromatic finder with crossline reticle. 6" Pyrex parabolic mirror—48" F.L. (f/8)—aluminized and overcoated —guaranteed to give theoretical limit of resolution. Mirror mount machined cast aluminum. Kellner eyepiece gives you 40X and a Goto combination eyepiece gives 60X and 120X. A Barlow lens is included to give 150X and 300X. Shipping weight 75 lbs.

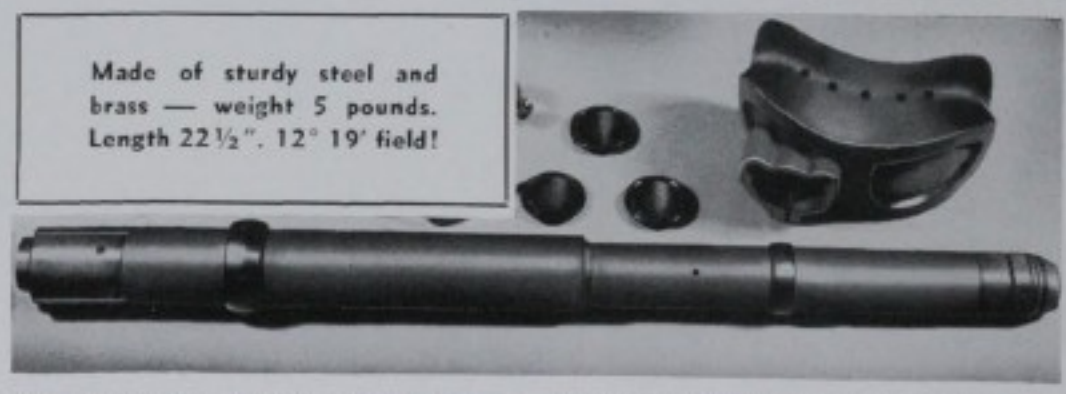
Stock #85,024-Y ..... $245.00 f.o.b.

M-70 3-POWER TELESCOPE

A $75 VALUE FOR ONLY $7.50

Bear In Mind!
Edmund Optical Items Are Sold With Money-Back Guarantee!

Made of sturdy steel and brass — weight 5 pounds. Length 22½". 12° 19' field!



Another fine quality instrument throughout — produced by America's leading optical manufacturers. Telescope consists of a Kellner eyepiece, reticle, 2 achromatic erector lenses, 1 achromatic objective lens (25-mm. diam.), and a protective window. All optics are low-reflection coated. Also included: a rubber eyeguard, and amber, red, and neutral filters for snapping on to eyepiece. All these telescopes equipped with small window through which reticle can be illuminated with small flashlight.

By removing 3 screws, you can separate scope into 2 pieces, one of which makes an excellent 6-power finder for an astronomical telescope on which reticle can be illuminated for night use. To give you some idea of the intrinsic value you are getting here — as surplus, the lenses alone would cost double the price we are asking for the entire instrument. Bear in mind, too, that the eyepiece by itself can be used for an astronomical telescope.

Stock #80,055-Y Completely boxed with protective absorbent, exactly as received from Army (new or near new) ..... $7.50 ppd.

Stock #80,051-Y Telescope only (used—good condition) ..... $4.00 ppd.

THE MOUNTING RINGS FROM OUR STANDARD 7-POWER FINDER CAN BE USED ON THE ABOVE M-70 TELESCOPE

Stock #50,075-Y Ring mounts per pair ..... $4.95 ppd.

EDMUND SCIENTIFIC CORP.

ACHROMATIC ASTRONOMICAL TELESCOPE OBJECTIVES

Real Quality at Bargain Prices
Make Wonderful Refractors

For three years we checked U.S., German, and Japanese manufacturers looking for one who could produce really good telescope objectives at a low price. A few times we ordered samples only to be disappointed in quality or final price. Finally, we found a Japanese optical engineer who designed some excellent astronomical objectives. We place orders with him. He then has these made, checking each one for quality. Thus, we are able to offer objectives we believe to be as good as those selling for two or three times our price.

Our 3" and 4" diameter objectives are air-spaced achromats, as air-spacing gives the lens designer four surfaces with which to correct aberrations, instead of only three as in a cemented achromat. The results are a beautiful, color-free image, sharp, clear, with very flat field, no bad zones, and full correction against coma.

Stock No.	Diam.	F.L.	Price	Comments
30,166-Y	3"	45"	$28.00	Not coated
30,190-Y	3"	45"	32.00	Coated
50,106-Y	4"	60"	60.00	Not coated
50,107-Y	4"	60"	69.00	Coated on four surfaces

Metal cells are available for the objectives above.
Stock #70,063-Y.....$11.95 for 4" objective
Stock #70,064-Y.....$10.95 for 3" objective

LOW COST, LONG F.L. ACHROMAT

Stock #30,187-Y 50" F.L., 2" diam., coated . . . $12.50 ppd.

Rack & Pinion Eyepiece Mounts

For Reflectors

For Refractors

Now you can improve performance in a most important part o. your telescope — the eyepiece holder. Smooth, trouble-free focusing will help you to get professional performance. Look at all these fine features: Real rack-and-pinion focusing with variable tension adjustment; tube accommodates standard 1¼" eyepieces and accessory equipment; lightweight aluminum body casting; focusing tube and rack of chrome-plated brass; body finished in black wrinkle paint. No. 50,077-Y is for reflecting telescopes, has focus travel of over 2", and is made to fit any diameter or type tubing by attaching through small holes in the base. Nos. 50,103-Y and 50,108-Y are for refractors and have focus travel of over 4". Will fit our 2⅜" I.D. and our 3⅜" I.D. aluminum tubes respectively.

Stock #50,077-Y (less diagonal holder) $9.95 ppd.
Stock #60,035-Y (diagonal holder only) 1.00 ppd.
Stock #50,103-Y (for 2⅜" I.D. tubing) 12.95 ppd.
Stock #50,108-Y (for 3⅜" I.D. tubing) 13.95 ppd.

HUYGENS EYEPIECES

Here are some really terrific values in eyepieces! The three eyepieces listed below are manufactured by one of the world's best producers of optical components. We have searched the world's markets, including Germany and France, to find a real quality eyepiece. The image clarity, the workmanship evidenced in the metal parts, will prove the skill and experience of Goto Optical Company, Tokyo. Guaranteed terrific buys!

HUYGENS TYPE — STANDARD 1¼" DIAM.
6 mm. (¼") Focal Length
Stock #30,063-Y ..... $8.50 ppd.
12.5 mm. (½") Focal Length
Stock #30,064-Y ..... $8.00 ppd.

COMBINATION EYEPIECE—10 mm. and 20 mm.
Stock #30,065-Y ..... $9.00 ppd.

SPITZ MOONSCOPE

See the Earth's Satellite

A precision-made 32-power reflecting telescope — by makers of Spitz Jr. Planetarium. Clearly reveals the craters of the moon, shows Saturn, Jupiter, other wonders of the heavens. Based on same principles as world's giant telescopes. Stands 36" high on removable legs. Adjustable 3" polished and corrected mirror. Fork-type altazimuth mount rotates on full 360° circle—swings to any location in the sky. Fascinating 28-page instruction book is included. Instrument packed in sturdy carrying case.

Stock #70,068-Y ..... $14.95 ppd.

7X — FINDER TELESCOPE — ACHROMATIC

Stock #50,080-Y Finder alone, less ring mounts $9.95
Stock #50,075-Y Ring mounts per pr., $4.95

ASTRONOMICAL TELESCOPE TUBING

Stock No.	I.D.	O.D.	Lgth.	Description	Price
80,038-Y	4⅞"	5¼"	46"	Spiral-wound paper	$2.50
85,008-Y	7"	7½"	60"	Spiral-wound paper	4.00
85,011-Y	2⅞"	3"	48"	Aluminum	6.00
85,012-Y	3⅞"	4"	60"	Aluminum	8.75
85,013-Y	4⅞"	5"	48"	Aluminum	9.00
85,014-Y	6⅞"	7"	60"	Aluminum	15.00

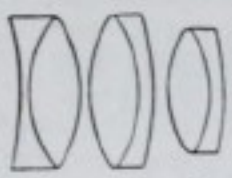
All tubing is shipped f.o.b. Barrington, N. J.

MOUNTED ERFLE EYEPIECE

68° FIELD OF VIEW

Consists of 3 coated achromats in metal mount with spiral focusing. F.L. 1¼". Diam. 54 mm., length 54 mm. War surplus. Govt. cost about $84.00. This is the type war-surplus bargain that will be talked about in years to come. Buy while you can.

Stock #5160-Y, $12.50 ppd.



ADAPTER

Provides 1¼" diameter mount to fit standard eyepiece holders.

Stock #30,171-Y ..... $3.95 ppd.
1¼" diam.

WAR SURPLUS

TELESCOPE EYEPIECE

Mounted Kellner Eyepiece, Type 3. 2 achromats, F.L. 28 mm., eye relief 22 mm. An extension added. O.D. 1¼". standard for all types of telescopes. Govt. cost $26.50.

Stock #5223-Y, $5.95 ppd.

DOUBLE AND TRIPLE YOUR TELESCOPE'S POWER WITH A BARLOW LENS

Stock #30,175-Y. Unmounted, O.D. 1-3/16". Coated. Fits in tubing listed below ..... $3.00 ppd.

Stock #30,140-Y. Mounted Achromatic Barlow Lens ..... $15.00 ppd.

30-day Money Back Guarantee as with all our Merchandise!

BRASS TUBING

2 pieces, 3" long, slide fitting. Blackened brass. I.D. 1-3/16". O.D. 1-5/16". To fit single-element Barlow above.

Stock #40,165-Y ..... $1.25 ppd.

"MAKE-YOUR-OWN" 4¼" MIRROR KIT

The same fine mirror as used in our Palomar, Jr., polished and aluminized, lenses for eyepieces and diagonal. No metal parts.

Stock #50,074-Y ..... $16.25 ppd.

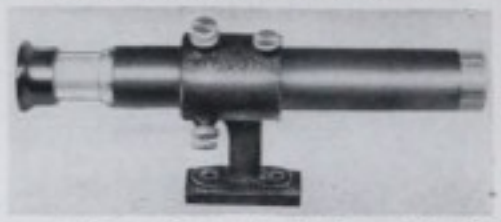
LATEST MODEL SPITZ Jr. PLANETARIUM

Designed by Armand Spitz. Projects nearly 400 stars, more than 70 constellations in their correct relationships. Use it in any darkened room of the house, project it on walls and ceiling. No batteries, works on ordinary household current. Two simple adjustments that show you the sky as it appears from any point in the Northern Hemisphere . . . for any time of night . . . for any month of the year! Rheostat brightness control. A 32-page book included free of extra cost. Contains valuable information about the stars, provides easy identification of the constellations. Also FREE — illuminated pointer.

About 14" high on a 7" x 7" base.

Stock #70,040-Y ..... $14.95 ppd.
Stock #70,059-Y Sky Zoo Projector $3.98 ppd.
Stock #70,060-Y Southern Hemisphere Projector ..... $3.98 ppd.

5X FINDER TELESCOPE



Has crosshairs for exact locating. You focus by sliding objective mount in and out. Base fits any diameter tube — an important advantage. Has 3 centering screws for aligning with main telescope. 20-mm. diam. objective. Weighs less than ½ pound.

Stock #50,121-Y ..... $8.00 ppd.

MISCELLANEOUS ITEMS

KELLNER EYEPIECE — 2" focal length (1¼" O.D.). Mount of black anodized aluminum.
Stock # 30,189-Y ..... $6.00 ppd.

60° SPECTROMETER PRISM — Polished surfaces 18 mm. x 30 mm. — flat to ½ wave length.
Stock #30,143-Y ..... $8.25 ppd.

BE SURE TO GET FREE CATALOG "Y"
Fantastic variety — never before have so many lenses, prisms, optical instruments, and components been offered from one source. Positively the greatest assembly of bargains in all America. Imported! War Surplus! Hundreds of other hard-to-get optical items. Write for Free Catalog "Y."

ORDER BY STOCK NUMBER . . . SEND CHECK OR MONEY ORDER . . . SATISFACTION GUARANTEED!

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The latest

Spitz Planetarium

has been installed at

Argentine Naval Academy

Buenos Aires, Argentina

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Spitz Laboratories, Inc.

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NEW - NEW - NEW

Star Time Calculator

Handy slide-rule type calculator enables you to obtain sidereal time in a matter of seconds. Good for any longitude, day of the year, standard time zone, and time of day. Accuracy to within several minutes is more than adequate for setting-circle use. Printed in two colors on sturdy 10" x 3½" cardboard. Reverse side lists 39 major star clusters and nebulae.

A useful tool for all who are interested in astronomy. Satisfaction guaranteed.

$1.00 postpaid

STAR TIME CALCULATOR

RR 2, Box 375, Buchanan, Michigan

Astronomy Films

16-mm. sound, 400-foot reels

I THE SUN
II THE MOON
III THE SOLAR SYSTEM
IV THE MILKY WAY
V EXTERIOR GALAXIES

Narration by Dr. Ruroy Sibley.

Highly commended by Visual Aid Departments, Film Libraries, Schools, Colleges and Educators throughout the country.

Slide Strips (35-mm.) and Slides (2 x 2), immediate delivery.

Each slide strip and set of slides is made from 20 selected frames of the corresponding reel. With Teaching Aid.

Catalogues on request.

International Screen Organization

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OBSERVER'S PAGE

Universal time is used unless otherwise noted.

Astrophotography for the Amateur—II

LAST MONTH I outlined methods for photographing sky objects such as entire constellations, smaller star configurations, and objects like open clusters and nebulae—each of these three groups requiring progressively larger plate scale.

There is a fourth group comprising diminutive objects such as planets and details on the moon. For these, projection photography through an eyepiece is in order. A simple projection camera, such as described here, can be made at home with a little skill; only three parts require some lathe work. This camera was made for use on my 5½-inch f/15 refractor. It can be quickly attached to the standard rack-and-pinion focusing motion of the telescope. The construction should be substantial, but light in order not to strain the focusing device. With a Graflex double filmholder for 3¼-by-4¼ cut film, the attachment weighs two pounds. The distance from the eyepiece to the film plane is 4".

The first picture shows the device attached to the telescope. At the center, the adapter tube slides into the telescope; it carries a square Bakelite baffle, which here is turned out of alignment with the square tube of the camera below it. In the square tube is seen the shutter, equipped with sponge-rubber stops; it is pulled by the cord, but may be rubber-band loaded for instantaneous exposures.

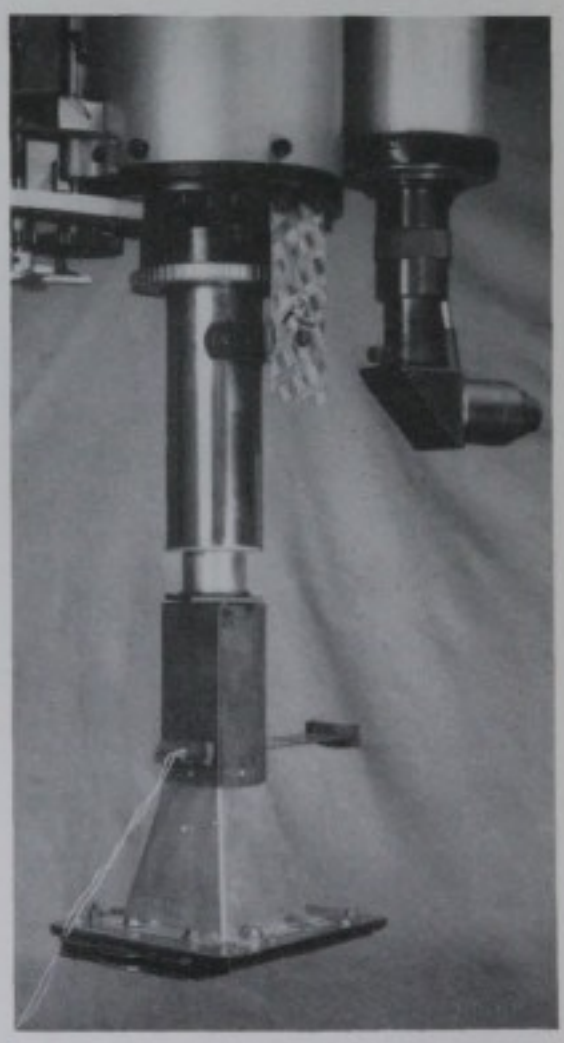
Below center in the photograph of the partly disassembled equipment the adapter tube for a 1¼" diameter eyepiece holder is seen again. On the larger end are soldered two collimating rings 1¾" apart, which have been machined true to fit tightly into the square tube. The Bakelite baffle slides between the first ring and a clamp that is adjusted with a screwdriver.

In attaching the camera, the square tube, 1¾" wide and 4" long, is pushed against the light trap, the clamp taking care of the variation of projection. The stainless-steel sliding shutter has a ¾" hole in its center, that may be seen in the picture, and it rides in two narrow slits ¾" from the other end of the square tube. The slits should be just large enough to allow the shutter blade to slide smoothly. In the picture of the parts, two small screws at the ends prevent the shutter from falling out, or sponge rubber may be used, as already mentioned. The small clip on the shutter may be attached to hold it open.

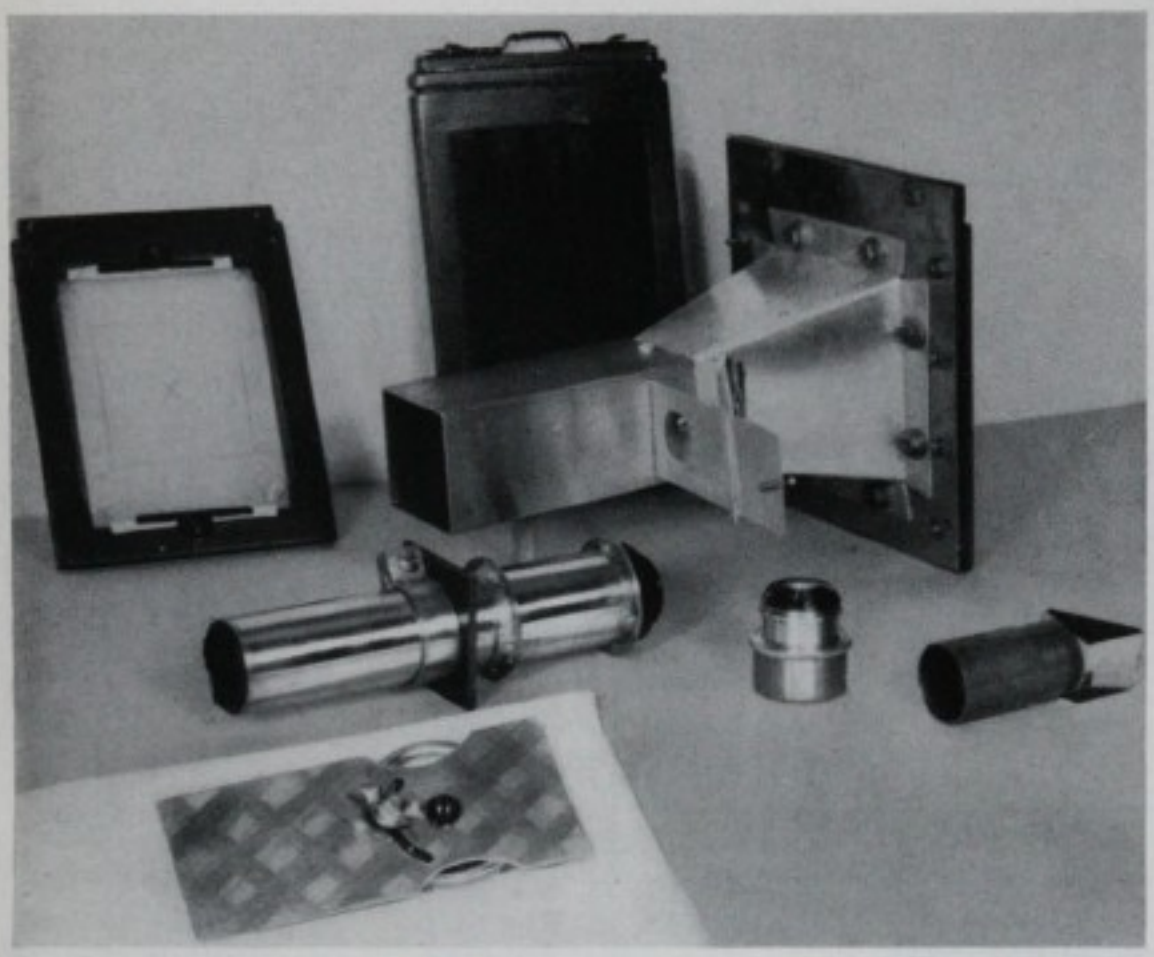
The main camera body is a pyramidal section of thin aluminum sheet riveted along one edge. The small opening of the pyramid is slit at the corners for ½", pushed into the square tube, squared on, and bolted. As can be seen, the larger end of the pyramid has ½"-wide flanges, and it is fastened to the camera back with 6-32 countersunk brass screws, washers, and nuts. To make the joints substantial, I punched the holes in a countersink hardwood mold; the oversized washers took care of the burrs on the outside. The back of the camera must be squared on carefully.

The back plate is a 5½" by 6" by 1/32" nickel sheet, sturdier than the aluminum pyramid, and covered with black cloth. At the 3" by 3" opening, the cloth was slit from corner to corner and the flaps were cemented into the camera pyramid to seal any light leaks. A black blotting paper liner also was cemented in to prevent reflections. Three cleats on the back, for holding the focusing frame or filmholder, were made from mahogany and brass with brass machine screws. A sliding member ¾" wide and 5" long, with diagonal slots and thumb tabs, holds the ground-glass frame or filmholder in place.

The 1-inch high-quality eyepiece shown gives a sharp field. Using it, the projected image can be varied between 4½ and 5 times the scale of the prime-focus



The camera for eyepiece projection photography is attached to the 5½-inch refractor. The guiding telescope is seen in the upper right. Next to it on the main tube is the stainless steel plate for locking the focus of the camera. The twin-slide filmholder is in place at the bottom of the picture.



The Pfleumer projection camera is shown partly disassembled. At the left is the focusing frame, and behind the camera is the filmholder. The magnifier with its prism is at the extreme right, next to the eyepiece. The latter screws into place against the second ring of the adapter tube, which is lying in the center foreground. In front of it is the focusing stop of stainless steel. In the square-tube part of the camera. the shutter has been pulled out to show the circular central hole.

image; larger and smaller plate scales are obtained by using other eyepieces. A 5x magnifier with a 90° prism attached is a great help in focusing the image. The focusing knob on the telescope has been replaced by a flat plate, which can be locked against accidental disturbance after the best focus has been found. This plate is in the left foreground of the picture of the parts, and is shown in the photograph of the complete assembly.

Some of the pictures I have taken with this apparatus and the attachments described in January will be printed here next month.

HANS PFLEUMER
596 First Ave.
New Brunswick, N. J.

SUNSPOT NUMBERS

The provisional sunspot numbers for November, 1955, issued by Zurich Observatory from observations there and at its Locarno and Arosa stations are given here, first the day of the month and then the number. American sunspot numbers for November will appear next month.

November 1, 106; **2,** 92; **3,** 77; **4,** 58; **5,** 51; **6,** 38; **7,** 71; **8,** 84; **9,** 115; **10,** 133; **11,** 156; **12,** 152; **13,** 142; **14,** 132; **15,** 122; **16,** 105; **17,** 95; **18,** 75; **19,** 55; **20-21,** 60; **22,** 61; **23,** 63; **24,** 70; **25,** 77; **26,** 81; **27,** 90; **28,** 97; **29,** 95; **30,** 93. Mean for November, 90.2.

Dr. M. Waldmeier, of Zurich Observa-

On To Mount Hamilton

Slide Set 10

217—Lick Observatory from west
218—Lick Observatory from east
219—Sierra Nevada Mountains and Yosemite Valley from Mt. Hamilton
220—Lick 36" refractor
221—Eye end of 36" refractor
222—Crossley reflector at Lick
223—Carnegie 20" double astrograph telescope
224—New Mills spectrograph
225—120" telescope dome
226—North America nebula, Cygnus, NGC 7000
227—California nebula, Perseus, NGC 1499
228—Helical planetary nebula, Aquarius, NGC 7293
229—Great Nebula in Orion
230—Nova Herculis, Mar. 10 and May 6, 1935
231—Polar star trails
232—Equatorial star trails
233—Pleiades and nebulosity
234—Milky Way in Sagittarius
235—Milky Way star clouds in Sagittarius
236—Milky Way in Aquila and Sagittarius
237—Head of Brooks' comet, Oct. 21, 1911
238—Finsler's comet, Aug. 28, 1937
239—Comet 1948I, Nov. 27, 1948
240—Relative dimensions of sun and planets

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tory, points out that the coming sunspot maximum will be of outstanding intensity, according to present indications, and may even surpass all maxima hitherto observed. Maximum spot activity should be reached about the middle of 1957, with the highest smoothed monthly relative number about 150, or even larger.

LOCATING VESTA

Observers with small telescopes will find it easy to pick up the asteroid Vesta on the night of February 21-22, as it passes only 5′ south of the 4th-magnitude star Mu Virginis. The minor planet is moving eastward, at about 10′ per day. The magnitude of Vesta will be approximately 6.8 at this time according to the *American Ephemeris*, but the Leningrad ephemerides of minor planets give 7.2. For a map of the path of Vesta, see page 145 of the January issue.

MOON PHASES AND DISTANCE

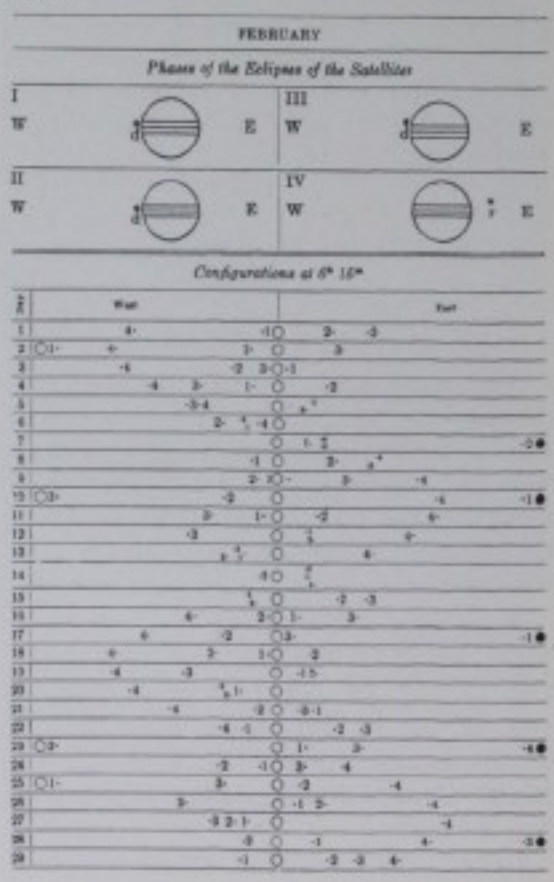
Last quarter	February	3, 16:08
New moon	February	11, 21:38
First quarter	February	19, 09:21
Full moon	February	26, 01:41
Last quarter	March	4, 11:53

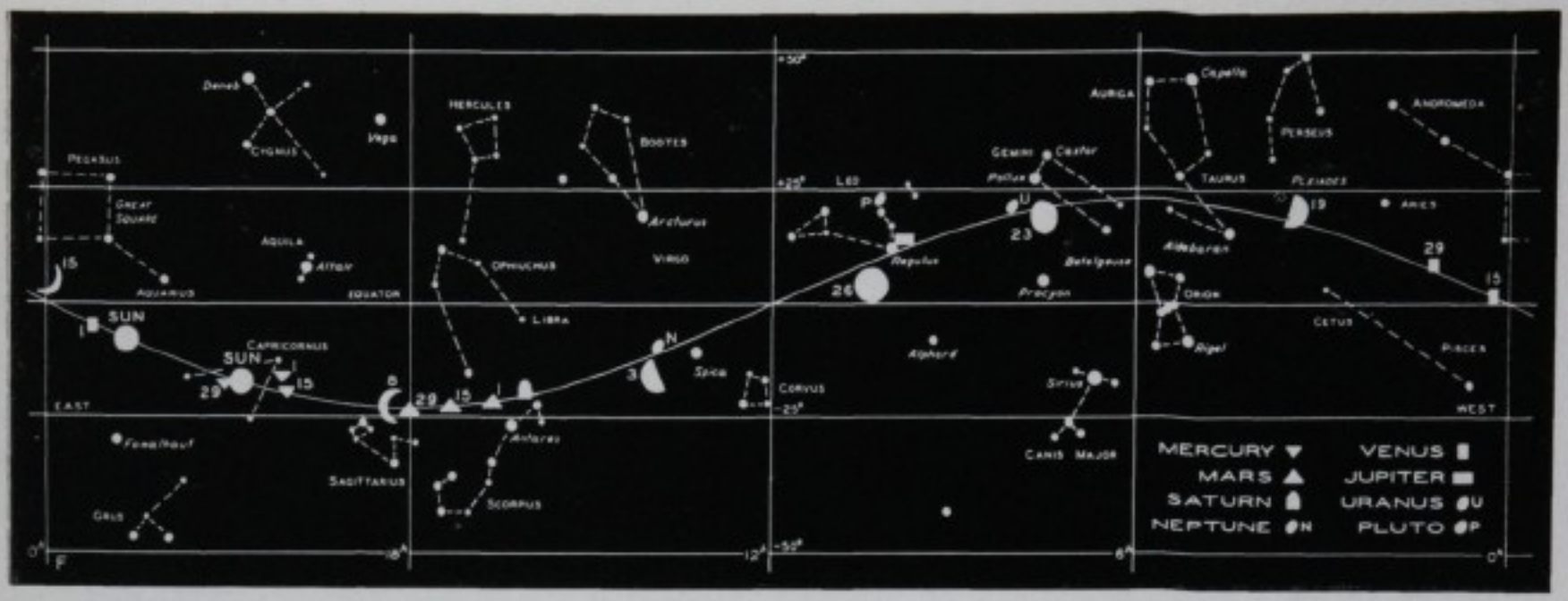
	February	Distance	Diameter
Apogee	7, 19h	252,100 mi.	29′ 27″
Perigee	23, 18h	225,900 mi.	32′ 52″
	March		
Apogee	6, 13h	251,500 mi.	29′ 32″

JUPITER'S SATELLITES

The configurations of Jupiter's four bright moons are shown below, as seen in an astronomical or inverting telescope, with north at the bottom and east at the right. In the upper part, *d* is the point of disappearance of the satellite in Jupiter's shadow; *r* is the point of reappearance.

In the lower section, the moons have the positions shown for the Universal time given. The motion of each satellite is from the dot toward the number designating it. Transits over Jupiter's disk are shown by open circles at the left, eclipses and occultations by black disks at the right. The chart is from the *American Ephemeris and Nautical Almanac*.





THE SUN, MOON, AND PLANETS THIS MONTH

The sun, on the ecliptic, is shown for the beginning and end of the month. The moon's symbols give its phase roughly, with the date marked alongside. Each planet is located for the middle of the month and for other dates shown.

Mercury can be viewed in the southeastern morning sky during the last two weeks of the month. Elongation is reached on February 21st, 26° 34′ west of the sun in longitude. At this time, the planet rises about 1¼ hours before the sun, shining at magnitude +0.3, in Capricornus.

Venus continues to move away from the sun in the evening sky. At the end of the month, it appears brilliant white in the west, setting 3½ hours after the sun. On the 15th, the planet is at magnitude −3.6, and its disk is 15″ in diameter, 75 per cent illuminated. Venus is in the constellation Pisces all February.

Mars may be seen in the morning sky, rising about four hours ahead of the sun. Continuing its eastward motion from Scorpius into Sagittarius, the red planet brightens to magnitude +1.2 by the end of the month. On the morning of the 6th, Mars appears just north of the moon; the planet will be occulted as seen from South Africa.

Jupiter will be in opposition to the sun on February 16th, and therefore visible all night. The planet is in retrograde motion to the west of Regulus in Leo, appearing at magnitude −2.1. The equatorial diameter of Jupiter is now 45″.

Saturn attains western quadrature with the sun on the 22nd, and hence rises at about midnight at the end of the month. Shining at magnitude +0.7, Saturn moves slowly eastward, passing about 1° north of Beta Scorpii in midmonth. The ring system continues to open out, presenting an inclination of 24°.8 on the 15th.

Uranus, above the horizon most of the night, can be viewed with slight optical aid. The planet is south of Mu Cancri and is moving slowly westward.

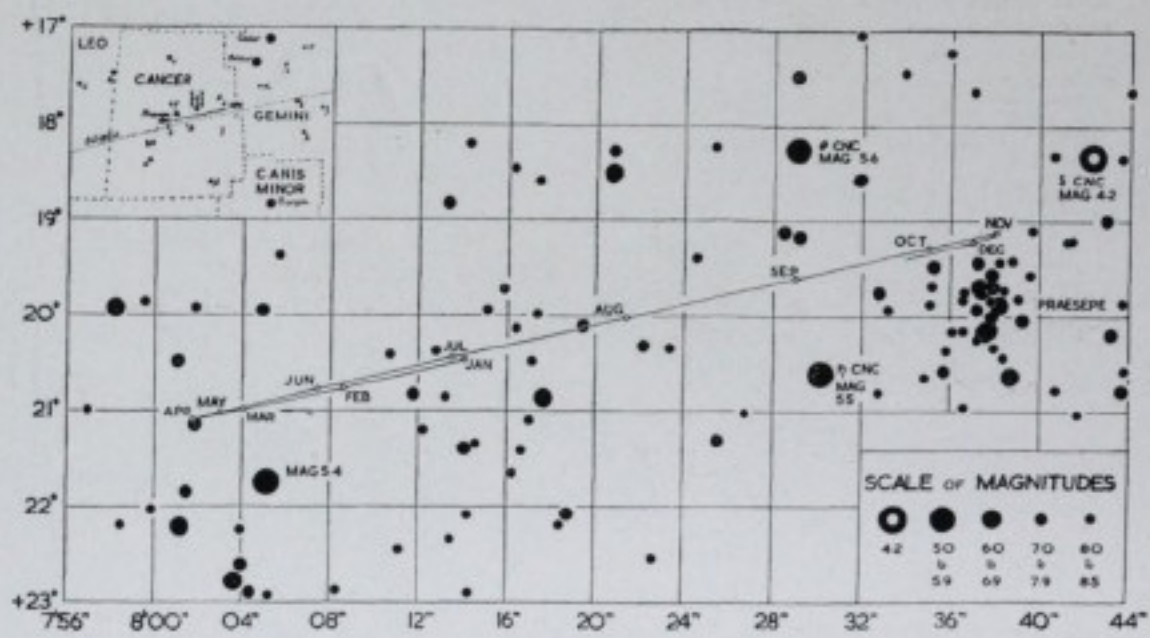
Neptune begins retrograde motion on February 2nd, preceding its opposition in April. It is in eastern Virgo, appearing at 8th magnitude. Its position on the 15th is 13ʰ 55ᵐ.2, −9° 56′ (1950).

Pluto reaches opposition with the sun on February 17th, at a distance of 33.8 astronomical units from the earth. This 14th-magnitude object is located south of Zeta Leonis, and its position at opposition is 10ʰ 14ᵐ.2, +22° 42′ (1950).

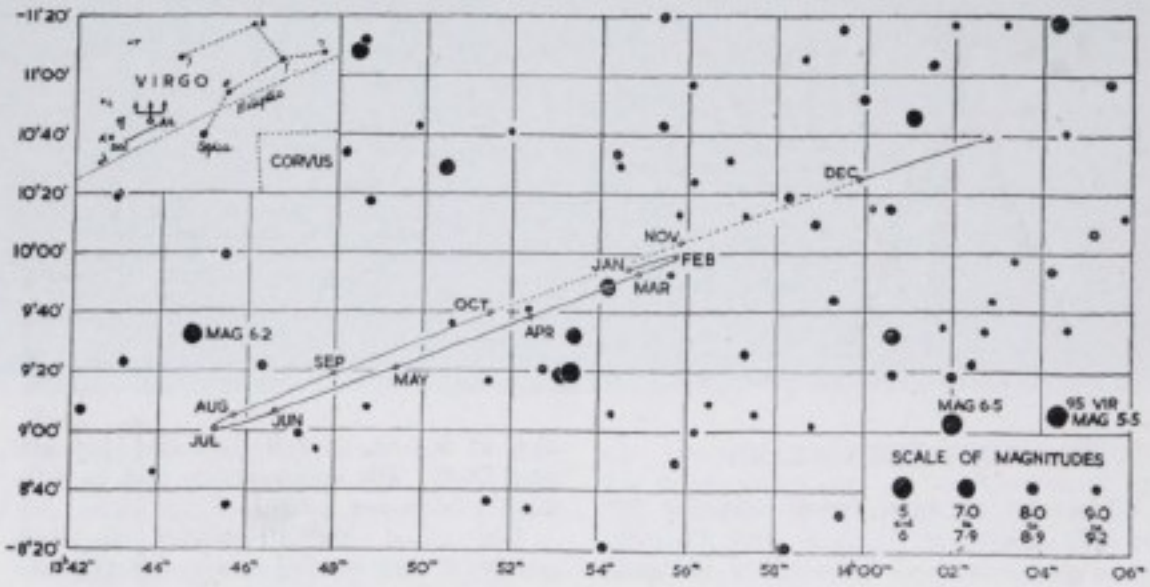
E. O.

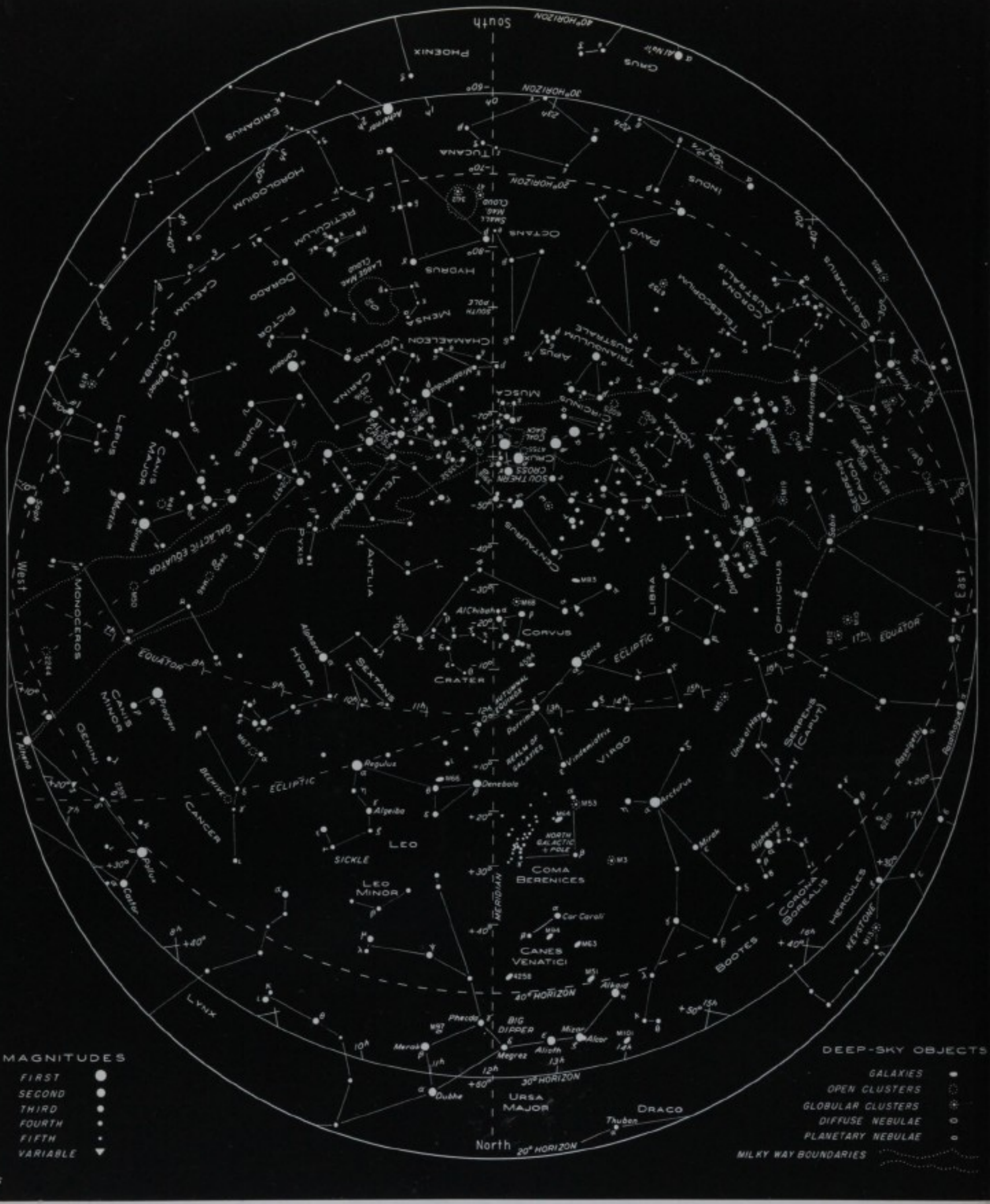
UNIVERSAL TIME (UT)

TIMES used on the Observer's Page are Greenwich civil or Universal time, unless otherwise noted. This is 24-hour time, from midnight to midnight; times greater than 12:00 are p.m. Subtract the following hours to convert to standard times in the United States: EST, 5; CST, 6; MST, 7; PST, 8. If necessary, add 24 hours to the UT before subtracting, in which case the result is your standard time on the day preceding the Greenwich date shown.



The path of Uranus among the stars of Cancer is shown above; that for Neptune among the stars in Virgo, below. In each case the field is inverted, with south at the top, as seen in an astronomical telescope. (The insets have north at the top.) The scales of the two charts are not the same. From the 1956 "Handbook" of the British Astronomical Association.



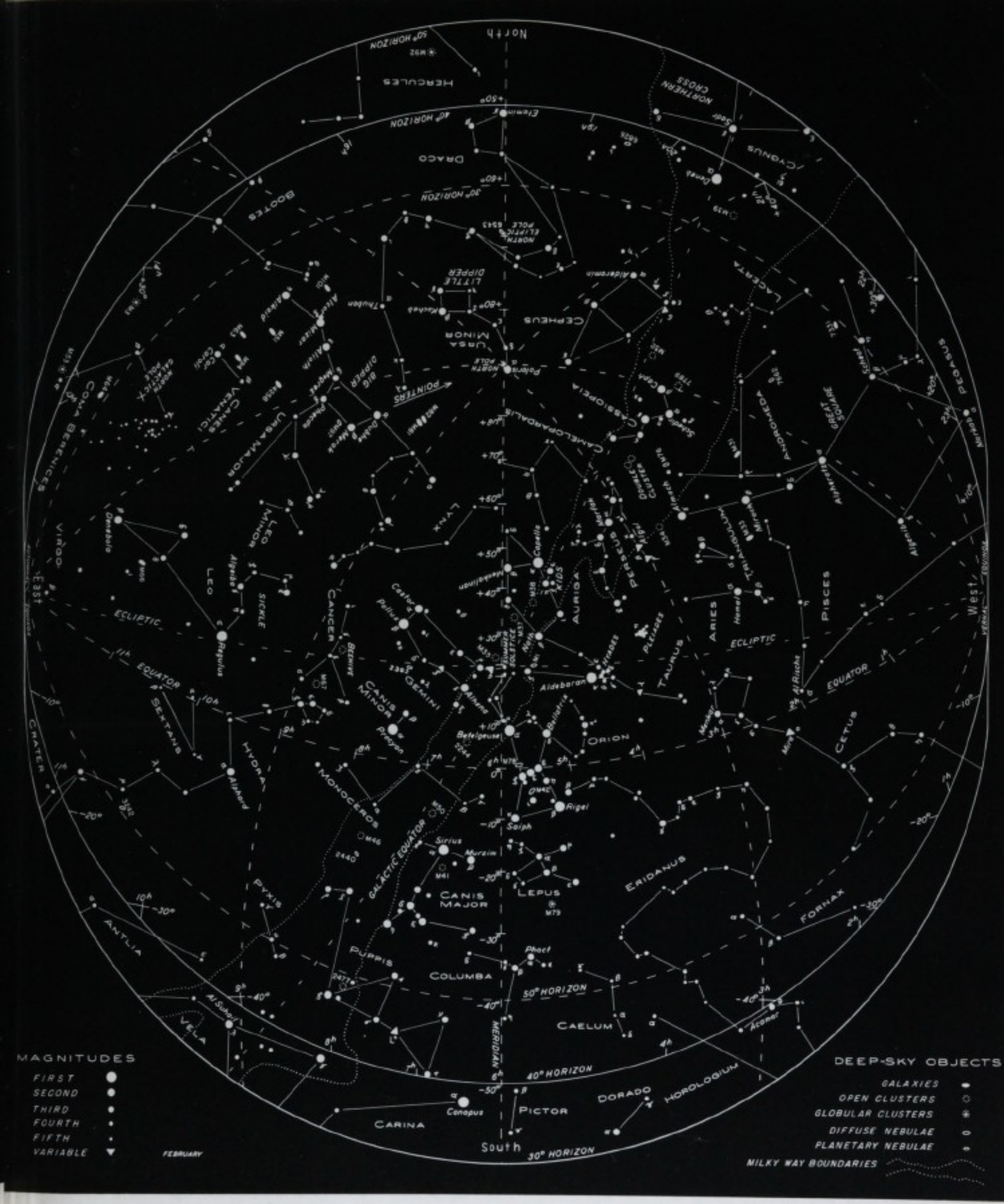


55

SOUTHERN STARS

The sky as seen from latitudes 20° to 40° south, at 11 p.m. and 10 p.m., local time, on the 7th and 23rd of April; also at 9 p.m. and 8 p.m. on May 7th and 23rd. For other dates, add or subtract ½ hour per week.

The three horizon circles on both northern and southern star charts make the maps usable over a wide range of latitudes, and also aid when the observer is visualizing the appearance of a constellation that is only partly above the horizon at a particular time.



MAGNITUDES
FIRST
SECOND
THIRD
FOURTH
FIFTH
VARIABLE

FEBRUARY

DEEP-SKY OBJECTS
GALAXIES
OPEN CLUSTERS
GLOBULAR CLUSTERS
DIFFUSE NEBULAE
PLANETARY NEBULAE
MILKY WAY BOUNDARIES

STARS FOR FEBRUARY

The sky as seen from latitudes 30° to 50° north, at 9 p.m. and 8 p.m., local time, on the 5th and 21st of February, respectively; also, at 7 p.m. and 6 p.m. on March 7th and 23rd. For other dates, add or subtract ½ hour per week.

When facing north, hold "North" at the bottom; turn the chart accordingly for other directions. The equator, ecliptic, galactic equator, and meridian are dashed curves, as are hour circles three hours east and west of the meridian.

DEEP-SKY WONDERS

AN OBSERVER in the Northern Hemisphere can, in principle, see into southern declinations as far as his co-latitude. That is, from 40° north latitude one should see to 50° south declination. Horizon haze, obstructions, and pure indifference usually keep the observer from reaching far south, but it is worth the effort—as the following objects will show. They were all seen from Manhattan, Kans., at altitudes from 5° to 15° above the horizon.

NGC 2090, in Columba at $5^h\ 45^m.2$, −34° 15′ (1950), was reported by Sir John Herschel to be a bright, partly resolved globular cluster, but it has been known for many years to be actually a spiral galaxy. Of the 12th magnitude, it is 2.5 minutes of arc long, and in a 7-inch refractor it looks rather like a globular. NGC 2298, at $6^h\ 47^m.2$, −35° 57′, in Puppis, is a real globular cluster with a diameter of 2′ and magnitude 10. With the 7-inch it was an easy object whose nature was readily apparent, its edge seemingly breaking down into individual stars.

In Canis Major at $6^h\ 27^m.6$, −31° 15′, NGC 2243 is a small cluster, 4′ in diameter, with a few bright stars. Apparently in big instruments it is fairly bright, but in the 7-inch it was not very attractive. NGC 2477, in Puppis at $7^h\ 50^m.3$, −38° 14′, is a cluster 25′ in diameter, with a naked-eye star at its edge. Were it farther north, it would be one of the better-known show objects of the sky, especially in larger telescopes. Also in Puppis, NGC 2451, like the preceding object, is a brilliant cluster containing a 4th-magnitude star. The cluster's position is $7^h\ 43^m.5$, −37° 51′.

NGC 2546, at $8^h\ 09^m.8$, −37° 14′, in Puppis, is a large cluster, not too rich, but full of 10th- to 13th-magnitude stars glowing with an even light. I saw it on a very clear night, and it was a most remarkable object. NGC 2818, in Pyxis at $9^h\ 14^m.0$, −36° 24′, was described by Sir John Herschel as a cluster in a planetary nebula. In the 7-inch the cluster was easily seen, and some nebulosity, though difficult, could be faintly traced to over 20′ in diameter. This object would make a fine test of far-southern seeing for observers in the United States.

WALTER SCOTT HOUSTON

GEMINID OBSERVATIONS

On the night of December 9-10, the astronomical section of the Oakland High School Science Association made visual observations of the Geminid meteor shower, from 9 p.m. PST until 1:30 the next morning. The observing site was a hill 1,110 feet high, east of Oakland.

Many meteors were observed, several brighter than zero magnitude. Of special interest was a reddish fireball of magnitude −5. Its diameter seemed about ½°, time of visibility four seconds, and path length 20°. It definitely was a member of the shower, and appeared in Ursa Major at 10:59 p.m.

Photography had been planned, but sky light and a near-by airplane beacon made this impossible.

JOHN E. WESTFALL
2328 Ivy Drive
Oakland 6, Calif.

MINIMA OF ALGOL

February 2, 0:20; 4, 21:09; 7, 17:58; 10, 14:48; 13, 11:37; 16, 8:26; 19, 5:16; 22, 2:05; 24, 22:54; 27, 19:44. March 1, 16:33; 4, 13:22; 7, 10:11; 10, 7:00.

These minima predictions for Algol are based on the formula in the 1953 *International Supplement* of the Krakow Observatory. The times given are geocentric; they can be compared directly with observed times of least brightness.

VARIABLE STAR MAXIMA

February 1, T Hydrae, 085**08**, 7.7; 6, S Canis Minoris, 072708, 7.5; 6, R Ophiuchi, 170**21**5, 7.6; 12, V Bootis, 142539, 7.9; 18, V Canum Venaticorum, 131546, 7.1; 24, R Centauri, 140**95**9, 5.9. March 1, T Centauri, 133**63**3, 6.1; 3, S Carinae, 100**66**1, 5.7; 7, R Sagittarii, 191**01**9, 7.2.

Some of these predictions for dates of maxima in early February have been revised by Mrs. Mayall from the provisional dates published here last month.

These predictions of variable star maxima are by the AAVSO. Only stars are included whose mean maximums magnitudes are brighter than magnitude 8.0. Some, but not all of them, are nearly as bright as maximum two or three weeks before and after the dates for maximum. The data given include, in order, the day of the month near which the maximum should occur, the star name, the star designation number, which gives the rough right ascension (first four figures) and declination (bold face if southern), and the predicted magnitude.

OCCULTATION PREDICTIONS

February 20-21 **o Tauri** 4.8, 5:25.0 +21-54.1, 9. Im: **A** 22:33.3 ..... 152; **B** 22:24.4 −1.8 −1.3 134.

February 23-24 **Alpha Cancri** 4.3, 8:56.1 +12-01.8, 13, Im: **H** 11:56.8 −0.2 −1.4 108; **I** 11:36.6 −0.5 −1.4 89.

March 2-3 **Delta Scorpii** 2.5, 15:57.7 −22-29.9, 21, Im: **E** 11:35.4 ..... 163. Em: **E** 12:14.5 ..... 213.

For stations in the United States and Canada, usually for stars of magnitude 5.0 or brighter, data from the *American Ephemeris* and the *British Nautical Almanac* are given here, as follows: evening-morning date, star name, magnitude, right ascension in hours and minutes, declination in degrees and minutes, moon's age in days, immersion or emersion; standard station designation, UT, **a** and **b** quantities in minutes, position angle on the moon's limb; the same data for each standard station westward.

The **a** and **b** quantities tabulated in each case are variations of standard-station predicted times per degree of longitude and of latitude, respectively, enabling computation of fairly accurate times for one's local station (long. **Lo**, lat. **L**) within 200 or 300 miles of a standard station (long. **LoS**, lat. **LS**). Multiply **a** by the difference in longitude (**Lo** − **LoS**), and multiply **b** by the difference in latitude (**L** − **LS**), with due regard to arithmetic signs, and add both results to (or subtract from, as the case may be) the standard station predicted time to obtain time at the local station. Then convert the Universal time to your standard time.

Longitudes and latitudes of standard stations are:

A	+72°.5,	+42°.5	**E**	+91°.0,	+40°.0
B	+73°.6,	+45°.5	**F**	+98°.0,	+31°.0
C	+77°.1,	+38°.9	**G**	Discontinued	
D	+79°.4,	+43°.7	**H**	+120°.0,	+36°.0
			I	+123°.1,	+49°.5

Read This Advertisement

Here is a combination of a Barlow and a particular ocular which gives outstanding results. It consists of our new Barlow and our 16.8-mm. (¾" focal length) Erfle eyepiece. While the Barlow was not specifically designed to work with this eyepiece, it does so to an astonishing degree. All images are sharp and hard to the very edge of the field.

The Barlow gives magnification up to slightly over three times that of the ocular alone. It is achromatic, coated, and mounted to the U. S. standard size of 1.250 inches.

The Erfle ocular has a field of approximately 68 degrees with excellent eye relief. The combination gives the equivalent focal length of slightly under 6 mm. Many users state it is far superior to any shorter focal length ocular of equivalent magnification.

The Barlow sells for $16.00 postpaid, and the Erfle for $14.75 postpaid. Both are guaranteed to perform as above stated or money refunded.

ORTHOSCOPIC OCULARS—All hard coated, standard 1¼-inch outside diameter.

28-mm.	$15.00	10.5-mm.	$16.25	4-mm.	$17.25
16.8-mm. (Erfle)	$14.75	7-mm.	$17.25	Barlow 3x	$16.00

Telescopics

1000 North Seward Street
Los Angeles 38, Calif.

Warranted to equal or surpass any oculars obtainable anywhere or money refunded.

Finished mirrors, mirror kits, spiders, elliptical flats, focusing devices, aluminizing.

Send for catalogue.

SKY-SCOPE

COMPLETE AS ILLUSTRATED $29.75

The full 3½-inch diameter reflecting type astronomical telescope that even the telescope makers talk about.

It has been sold for more than 16 years and now is on display in at least two U. S. planetaria. It will show mountains and craters on the moon, Saturn's rings, Jupiter's four moons and the planet's markings, and close double stars with guaranteed observatory clearness. Skyscope enjoys worldwide distribution.

Every instrument, with its ¼-wave, aluminized mirror, is individually tested before being packed for shipment. We suggest that before buying you inquire at almost any local astronomy society about the efficiency of Skyscope. *100% American-made.*

We invite your attention to our free and straightforward descriptive brochure which also shows a photograph of the individual parts used.

125-power and 35-power extra eyepieces	$5.15 each
Six-power finder, with brackets	$7.50
Holder for extra eyepieces	$1.00

THE SKYSCOPE CO., INC. 475-s Fifth Avenue, New York 17, N. Y.

Brandon Orthoscopic Oculars

☆ During the past ten years, we have produced several thousand of our orthoscopic oculars, which have been highly praised by the casual amateur observer as well as the serious professional astronomer throughout the world.

☆ Many attempts have been made to duplicate both the appearance and performance of these oculars. The market has been flooded with war-surplus optics and Oriental and European imports for which the performance is often mediocre. These less satisfactory eyepieces have actually increased our sales.

☆ To keep pace with the demand, we have established our research and production facility in Puerto Rico. Here we have willing American labor, ideal climatic conditions to produce quality optical components, and unlimited visibility both day and night for field testing. We are confident we can produce the finest astronomical components available at competitive prices.

☆ Rather than resort to high-pressure claims, we prefer to let our oculars sell themselves. We only ask that before you purchase your next eyepiece you consider its performance. This may be confirmed for Brandon oculars by consulting your local planetarium or observatory, your astronomical society, or your college or university science department. Of course our best salesman is the owner of a Brandon ocular.

☆ We urge you to purchase an eyepiece 1¼ inches in diameter, regardless of who makes it—most imported eyepieces have substandard diameters, with necessarily smaller lens components that seriously restrict the field of view.

☆ The painstaking care that you have put into your mirror or telescope can be nullified by an inferior eyepiece. We sincerely believe the Brandon orthoscopic ocular is the best available, regardless of price. Here's why:

1. Four-element design giving a flat, beautifully corrected field of 50° covering more than 160 per cent of the area of the conventional Ramsden for the same power. This eyepiece is a "must" for RFT work.
2. Precision optical elements, magnesium fluoride hard coated, increasing the light transmission approximately 10 per cent.
3. Simple take-down for cleaning.
4. Precision metal parts black anodized for anti-reflection and ground to 1¼" O.D.
5. Clean mechanical design permitting comfortable observation and ease of focusing.

These eyepieces are produced in 4-mm., 8-mm., 16-mm., and 32-mm. effective focal lengths.

$15.95 each, postpaid

Astronomical Objectives

We can also ship from stock quality astronomical objectives with the following features:

1. Superior optical design utilizing a larger air separation. Color corrected on C and F and hand corrected to reduce residuals to a minimum. Completely free of coma.
2. Glass-air surfaces magnesium fluoride coated, increasing light transmission approximately 10 per cent.
3. Quality optical glass precision annealed and held to one ring test plate match.
4. Cell made to precision tolerances and suitably coated to prevent stray light reflections. Each cell engraved with effective focal length and serial number.

These objectives are supplied with cells and rigidly tested on double stars for resolving power before being sold:

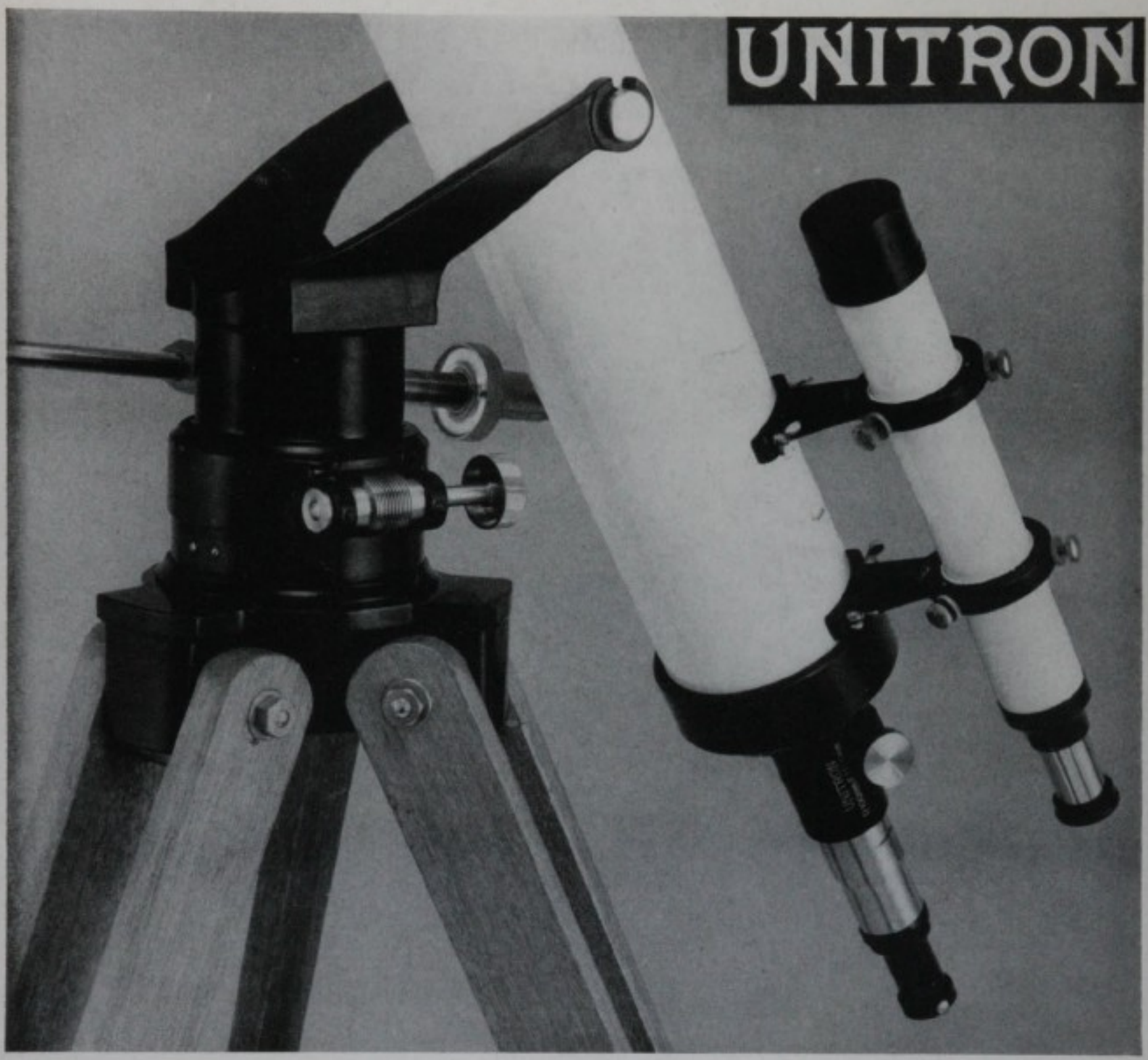
3" Clear Aperture	**45" Effective Focal Length**	**$ 62.00**
4" Clear Aperture	**60" Effective Focal Length**	**$138.00**

Complete cell dimensions upon request.

Your order, accompanied by your check or money order, will be filled immediately and sent airmail insured.

Brandon Instruments

GUAYNABO, PUERTO RICO



UNITRON's 4" Altazimuth Refractor for 1956 offers unexcelled value in *Large* Aperture at *Low* Price

Here is the logical choice for the amateur whose requirements call for a large instrument but where budget (or family ties) will not permit the purchase of one of the more expensive equatorial models. The UNITRON 4" Altazimuth Refractor, Model 150, is an ideal basic instrument to own, since when you get a raise (or if you discover uranium in your back yard) you can always add the equatorial mounting, photographic guide telescope, clock drive, fixed pier, and other features and accessories found in our more expensive equatorial models. Model 150 is also recommended for millionaires who need to carry the telescope in their private planes, since the mounting is somewhat more portable than that used in the equatorials.

This rock-sturdy altazimuth mounting is equipped with slow-motion and rapid-motion controls for both altitude and azimuth. The azimuth slow motion now features a newly designed worm-gear mechanism which allows continuous variation over 360°.

The UNITRON 4" Altazimuth Refractor is priced at only $465.00, complete. This includes tripod and mounting, handy tripod shelf to hold accessories, large 10x 42-mm. view finder, choice of UNIHEX Rotary Eyepiece Selector or star diagonal and erecting prism system for terrestrial observation, sunglass, solar aperture diaphragm, cabinets, and eyepieces for 250x, 214x, 167x, 120x, 83x, and 60x. Additional eyepieces for 375x, 300x, and 38x, as well as accessories such as the sun projecting screen, astro-camera, DUETRON, etc., are available at extra cost.

For only $116.00 down, you can own this mighty UNITRON which offers all the many advantages and conveniences of the refractor type of design. With Model 150, you will be equipped to take fullest advantage of this year's favorable opposition of Mars. You know that you will buy a UNITRON sooner or later, so why delay any longer. Your order sent today will bring you many hours of pleasant observing in the years to come.

See pages 178 and 179.

United Scientific Co. 204-206 MILK STREET, BOSTON 9, MASS.